

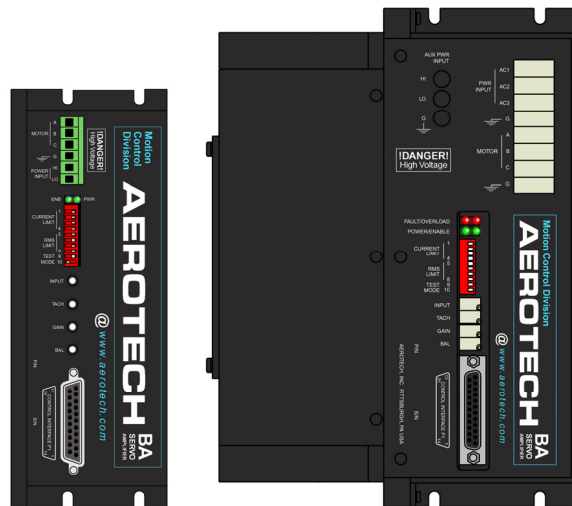
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## BA50/75/100 SERIES

### USER'S MANUAL

P/N: EDA140 (V1.4)

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If you should have any questions about the BA50, 75, or 100 and/or comments regarding the documentation, please refer to Aerotech online at:

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Our website is continually updated with new product information, updated manuals, free downloadable software and special pricing on selected products.

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**TABLE OF CONTENTS**

|                                                        |            |
|--------------------------------------------------------|------------|
| <b>CHAPTER 1: INTRODUCTION.....</b>                    | <b>1-1</b> |
| 1.1. Product Overview .....                            | 1-1        |
| 1.2. Models, Options and Packages .....                | 1-2        |
| 1.3. BA Drive Package.....                             | 1-3        |
| 1.4. Hardware Overview and Function .....              | 1-4        |
| 1.4.1. Motor and AC Power Connections.....             | 1-4        |
| 1.4.2. DIP Switch.....                                 | 1-5        |
| 1.4.3. Potentiometers (POTs).....                      | 1-6        |
| 1.4.4. Connector P1 and Enable Indicator .....         | 1-6        |
| 1.4.5. I/O Circuitry .....                             | 1-9        |
| 1.5. Safety Procedures and Warnings .....              | 1-11       |
| <b>CHAPTER 2: INSTALLATION AND OPERATION .....</b>     | <b>2-1</b> |
| 2.1. Jumper Selections .....                           | 2-1        |
| 2.2. Wiring, Grounding, and Shielding Techniques ..... | 2-4        |
| 2.2.1. Minimizing EMI Interference.....                | 2-4        |
| 2.2.2. Minimizing 50/60 HZ Line Interference .....     | 2-5        |
| 2.3. Integrated Configurations .....                   | 2-7        |
| 2.3.1. Velocity Command Configuration.....             | 2-7        |
| 2.3.2. Current Command Configuration .....             | 2-8        |
| 2.3.3. Dual-Phase Command Configuration.....           | 2-9        |
| 2.4. Control Connections .....                         | 2-10       |
| 2.4.1. Setup - Torque Command Mode (Current).....      | 2-10       |
| 2.4.2. Setup - Velocity Command Mode .....             | 2-10       |
| 2.4.3. Setup - Dual-Phase Command Mode.....            | 2-12       |
| 2.5. Motor Phasing Process.....                        | 2-13       |
| 2.5.1. Determining Phase/Hall Sequence.....            | 2-13       |
| 2.6. Current Regulator Adjustment.....                 | 2-15       |
| <b>CHAPTER 3: TECHNICAL DETAILS.....</b>               | <b>3-1</b> |
| 3.1. Part Number and Ordering Information.....         | 3-1        |
| 3.2. Electrical/Environmental Specifications .....     | 3-2        |
| 3.3. BA Amplifier Dimensions .....                     | 3-6        |
| <b>CHAPTER 4: TROUBLESHOOTING .....</b>                | <b>4-1</b> |
| 4.1. Amplifier Related Problems.....                   | 4-1        |
| 4.2. Fuse Replacement .....                            | 4-3        |
| 4.3. Cleaning .....                                    | 4-4        |
| <b>APPENDIX A: GLOSSARY OF TERMS.....</b>              | <b>A-1</b> |
| <b>APPENDIX B: WARRANTY AND FIELD SERVICE .....</b>    | <b>B-1</b> |
| <b>APPENDIX C: CABLE DRAWINGS .....</b>                | <b>C-1</b> |
| Description .....                                      | C-1        |
| <b>INDEX</b>                                           |            |





**LIST OF FIGURES**

|              |                                                                       |      |
|--------------|-----------------------------------------------------------------------|------|
| Figure 1-1.  | BA50 /75/100 Series Amplifiers.....                                   | 1-1  |
| Figure 1-2.  | Functional Diagram .....                                              | 1-3  |
| Figure 1-3.  | Amplifier Hardware .....                                              | 1-4  |
| Figure 1-4.  | Fault Output .....                                                    | 1-9  |
| Figure 1-5.  | Enable/Shutdown Inputs .....                                          | 1-9  |
| Figure 1-6.  | $\pm$ Limit Inputs.....                                               | 1-10 |
| Figure 1-7.  | Hall and Encoder Inputs.....                                          | 1-10 |
| Figure 2-1.  | BA50/75/100 Board Assembly (Jumpers Shown in Default) .....           | 2-3  |
| Figure 2-2.  | Wiring to Minimize EMI and Capacitive Coupling.....                   | 2-5  |
| Figure 2-3.  | Back-Propagation Line Filter Connection .....                         | 2-5  |
| Figure 2-4.  | Isolation Transformer Connection (eliminates torque disturbance)..... | 2-6  |
| Figure 2-5.  | Velocity Command Configuration .....                                  | 2-7  |
| Figure 2-6.  | Current Command Configuration .....                                   | 2-8  |
| Figure 2-7.  | Dual-Phase Command Configuration .....                                | 2-9  |
| Figure 2-8.  | Command Signal Adjustment Portion of the Pre-Amplifier Circuit .....  | 2-11 |
| Figure 2-9.  | Motor Phasing.....                                                    | 2-14 |
| Figure 2-10. | Three-Phase Current Regulator Circuit.....                            | 2-15 |
| Figure 3-1.  | BA50 Dimensions (Front View).....                                     | 3-7  |
| Figure 3-2.  | BA50 Preferred Mounting (Side View).....                              | 3-8  |
| Figure 3-3.  | BA75/100 Dimensions (Front View).....                                 | 3-9  |
| Figure C-1.  | BA Feedback Cable (PFC).....                                          | C-1  |
| Figure C-2.  | BA Series Light Duty Brushless Motor Cable (PMC) (BA 50 only).....    | C-2  |





**LIST OF TABLES**

|            |                                               |     |
|------------|-----------------------------------------------|-----|
| Table 1-1. | BA Models and Voltage Configurations.....     | 1-2 |
| Table 1-2. | DIP Switch Functions .....                    | 1-5 |
| Table 1-3. | Potentiometer Functions .....                 | 1-6 |
| Table 1-4. | Connector P1 Pinouts.....                     | 1-7 |
|            |                                               |     |
| Table 2-1. | Jumper Selections .....                       | 2-2 |
|            |                                               |     |
| Table 3-1. | Ordering Information .....                    | 3-1 |
| Table 3-2. | Electrical Specifications.....                | 3-2 |
|            |                                               |     |
| Table 4-1. | Amplifier Faults, Causes, and Solutions ..... | 4-1 |
| Table 4-2. | Fuse Replacement Part Numbers .....           | 4-3 |

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## DECLARATION OF CONFORMITY

**Manufacturer's Name and Address**

Aerotech, Inc.  
101 Zeta Drive  
Pittsburgh, PA 15238-2897

Declares that the product:

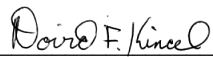
**Product Name:** Brushless Servo Amplifier (BA 50/75/100)

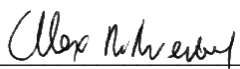
Conforms to the following product specifications:

**LVD:** UL 61010-1  
CAN/CSA C22.2 No. 1010-1  
IEC 1010-1

and complies with EMC directive 89/336/EEC.

Pittsburgh, PA  
January, 2004

David F. Kincel   
Quality Assurance Manager

Alex Weibel   
Engineer Verifying Compliance

**General notes concerning the test setup.**

The Brushless Servo Amplifier required external fuse or circuit breaker protection on all AC Mains inputs. The BA 50 amplifier required a 25 Amp fuse/breaker on AC Main inputs. The BA 75 & 100 required a 30 Amp fuse/ breaker on AC Main inputs.

▽ ▽ ▽



## CHAPTER 1: INTRODUCTION

### In This Section:

- Product Overview ..... 1-1
- Models, Options and Packages ..... 1-2
- BA Drive Package ..... 1-3
- Hardware Overview and Function ..... 1-4
- Safety Procedures and Warnings ..... 1-11

### 1.1. Product Overview

The BA (High Current) Series amplifiers are highly reliable brushless servo amplifiers (refer to Figure 1-1) that are easily adaptable to drive brush or brushless servomotors. The amplifiers are available in three peak output current ratings of 50, 75, and 100 amps. The BA amplifier package is a complete modular unit that includes heat sink, metal cover, and bus power supply that operates from 56-230 VAC. The BA drives provide the designer with servo drive flexibility for use in applications such as:

- Machine tools
- Packaging
- Labeling
- X-Y stages
- Inspection
- Medical
- Winding
- Semiconductor fabrication
- and food processing

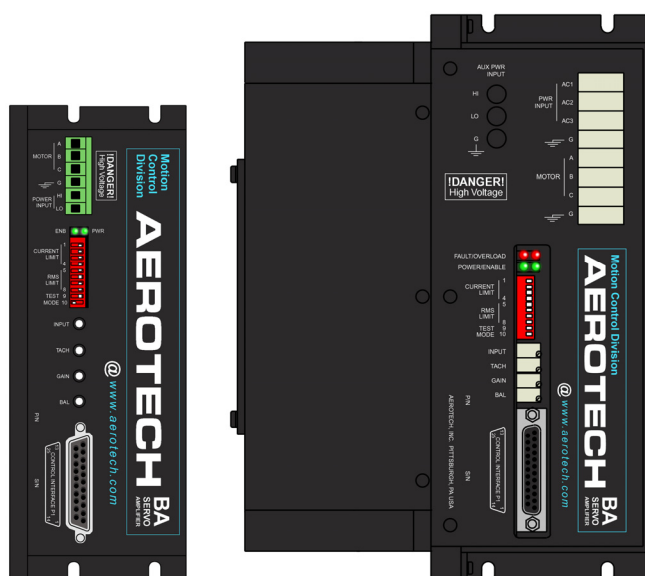


Figure 1-1. BA50 /75/100 Series Amplifiers

## 1.2. Models, Options and Packages

The BA high current drives are available in three models with continuous power, ranging from 6,000 to 10,000 watts. A list of these models and the available voltage configurations is shown in Table 1-1.

**Table 1-1. BA Models and Voltage Configurations**

| Model | Standard Voltage Configuration | Peak Output Current | Continuous Output Current (peak) | DC Bus Voltage Range (Nominal VDC) |
|-------|--------------------------------|---------------------|----------------------------------|------------------------------------|
| BA50  | 320V                           | 50A                 | 25A                              | 80-320VDC                          |
| BA75  | 320V                           | 75A                 | 37A                              | 80-320VDC                          |
| BA100 | 320V                           | 100A                | 50A                              | 80-320VDC                          |

The BA drives feature self-commutation with digital Hall effect feedback signals. The BA drives include a 5 VDC, 250 mA supply to power encoders, and Hall effect devices (HEDs). Each model is jumper selectable, providing the capability to drive both brush and brushless motors. Complete electrical isolation is provided between the control stage and the power stage for all models of the BA series. This is accomplished with a transformer isolated control voltage power supply and opto-isolation of the drive signals, current feedback signals and fault signal between the control and power stages. Each drive is fully protected against the following fault conditions:

- Control power supply under voltage
- RMS current limit exceeded
- Power stage bias supplies under voltage
- Over temperature
- Over current
- Output short circuits (phase to phase and phase to ground)
- and DC bus overvoltage (detected if shunt fuse is open)

Operating modes include current command, velocity command or dual-phase command (for brushless modes of operation only). For brush modes of operation, the available operating modes are current command and velocity command. Differential inputs are used for better noise immunity. Velocity feedback is from either an encoder or tachometer and logic inputs include directional current limits and shutdown. Fault, current, and velocity outputs simplify monitoring drive status.

### 1.3. BA Drive Package

The standard package includes the heat sink, cover, shunt regulator, control power supply, and the bus power supply that operates from 56-230 VAC. The power supply is included with the standard package for off-line operation without the need for an isolation transformer. Figure 1-2 is a functional diagram showing the standard package configuration.

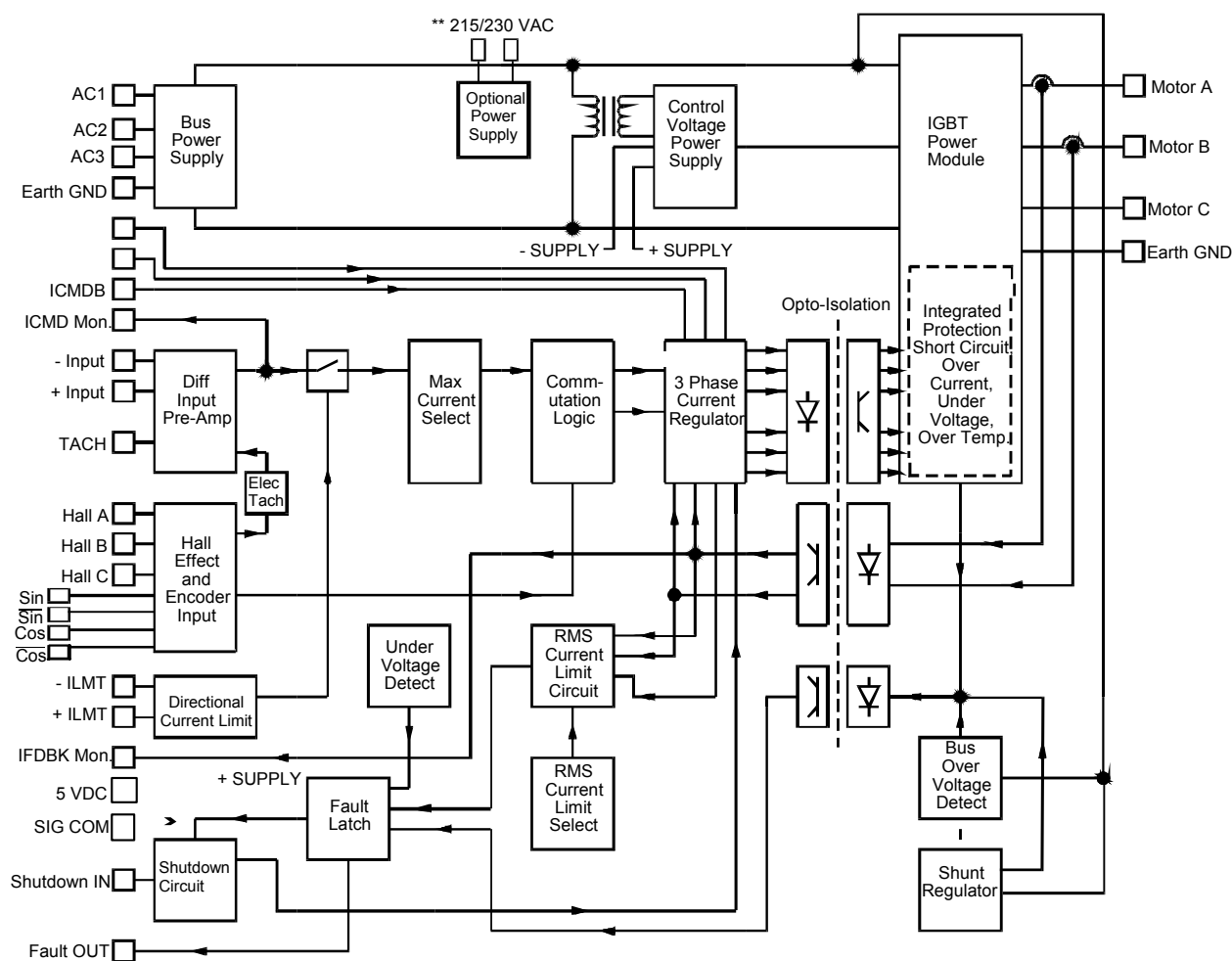


Figure 1-2. Functional Diagram

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A secondary 115/230 VAC connection is necessary if the DC bus power is required to operate below 80 VDC.



## 1.4. Hardware Overview and Function

The BA series consist of two power connections (motor power and input power), four potentiometers, a 10-position DIP switch, an enable LED indicator lamp, a fault/overload indicator lamp, and a 25-pin “D” style connector. Refer to Figure 1-3 for locations.

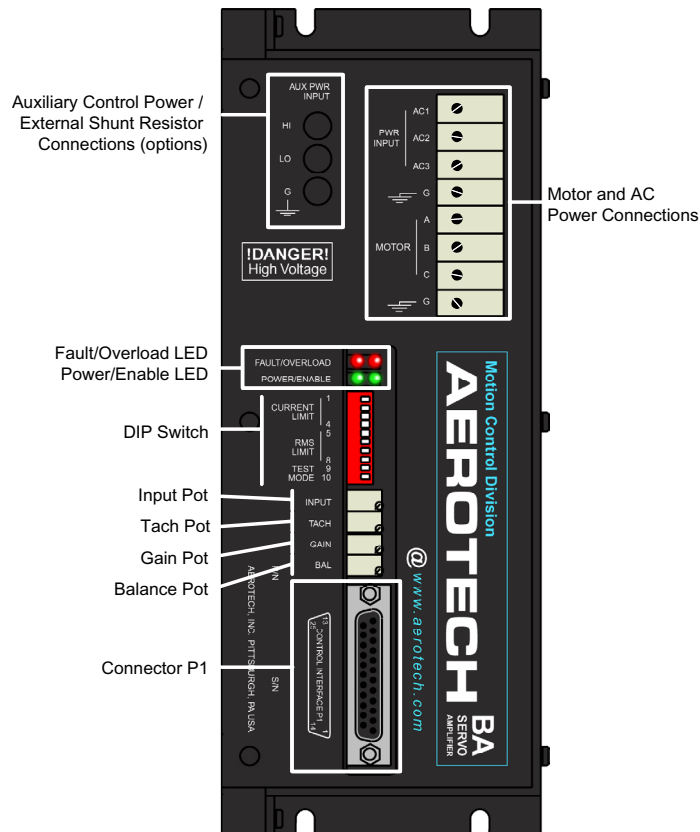
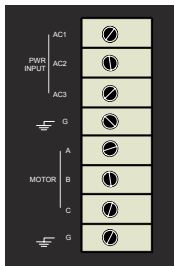


Figure 1-3. Amplifier Hardware



### 1.4.1. Motor and AC Power Connections

The three phase motor terminal connections are made at connections **A**, **B**, and **C**. This area is designated as such on the amplifier.

Input power to the BA series amplifier is made at the **AC1**, **AC2**, and **AC3** terminals with earth ground connected to  $\varnothing$  (ground). Single or three-phase power can be made at these connections. The BA 50 can be operated on three or single phase AC power. For single phase operation, connect the AC power to **AC1** and **AC2**.

For the BA75 and BA100, only three phase-input power should be used.

### 1.4.2. DIP Switch

There is a 10-position DIP switch on the BA drive that provides four discrete functions. The switch permits the user to control maximum allowable current to the motor, continuous output current, velocity or current operational mode, and test mode. Figure 1-3 shows the location of this switch on the BA drive. Refer to Table 1-2 for the exact switch functions.

**Table 1-2. DIP Switch Functions**

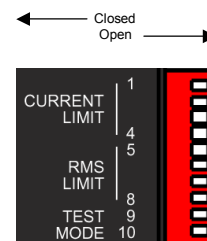
|                                                                                                                   | Switches | Position | Function                                                                                                                                                                         |
|-------------------------------------------------------------------------------------------------------------------|----------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Current limit Peak</b>                                                                                         | *1       | closed   | Peak is 6% of Ipeak                                                                                                                                                              |
|                                                                                                                   | *2       | closed   | Peak is 13% of Ipeak                                                                                                                                                             |
|                                                                                                                   | *3       | closed   | Peak is 27% of Ipeak                                                                                                                                                             |
|                                                                                                                   | *4       | closed   | Peak is 54% of Ipeak                                                                                                                                                             |
| * These switches affect the GAIN adjustment of the velocity loop. Maximum gain adjustment when 1 to 4 are closed. |          |          |                                                                                                                                                                                  |
| <b>Continuous Current Peak*</b>                                                                                   | 5        | closed   | Icont is 3% of Ipeak                                                                                                                                                             |
|                                                                                                                   | 6        | closed   | Icont is 7% of Ipeak                                                                                                                                                             |
|                                                                                                                   | 7        | closed   | Icont is 14% of Ipeak                                                                                                                                                            |
|                                                                                                                   | 8        | closed   | Icont is 27% of Ipeak                                                                                                                                                            |
| * The maximum allowable continuous current is 54% of peak current.                                                |          |          |                                                                                                                                                                                  |
| <b>Test</b>                                                                                                       | 9        | closed   | Closing this position allows the Balance potentiometer to manually control motor velocity or torque without the need of an input signal depending upon the setting of switch 10. |
| <b>Mode</b>                                                                                                       | 10       |          | Velocity/Current mode - closing this position enables the current mode.                                                                                                          |

Switches 1-4 affect the full-scale current output range of the amplifier when in current (and in velocity) mode. When all four switches are closed, the peak current range is not limited. Closing each switch effectively limits the output range of the amplifier by a factor associated with that switch. For example closing only SW1-4 (54%) on a BA50 limits the output current to 27 Amp. Therefore, a 10 Volt input signal would produce a 27 Amp output; similarly, a 5 Volt input would produce a 13.5 Amp output ( $5V / 10V * 27A$ ). It should be noted that switches 1-4 have no effect in dual-phase mode.

Switches 5 through 8 determine the level where the continuous output current the BA amp protection circuit will produce a fault. This type of protection is known as an electronic fuse.

For low duty cycle and low acceleration system requirements, set the DIP switches equally or to the next lower switch setting. For high duty cycle and high acceleration system requirements, set the DIP switches equally or to the next higher switch setting.

Closing DIP switches 1 through 4 will allow peak current. Closing switches 5 through 8 will allow 54% peak continuous current for two seconds.



The following examples should be used as a guideline for setting the DIP switches.

#### Example for a BA50 - Setting RMS Current Limits

To set the continuous current limit to 10A:

$10\text{A Continuous RMS} \times 1.414 = 14.14\text{A continuous peak}$

$(14.14\text{A continuous peak}/50\text{A max peak}) \times 100 = 28\%$ .

Open switches 5, 6, and 7; close switch 8.

#### Example for BA50 - Setting Current Limits

To set the peak current to 37A:

##### Peak Current

$(35\text{A peak}/50\text{A max peak}) \times 100 = 75\%$

Close switches 3 and 4; open switches 1 and 2.

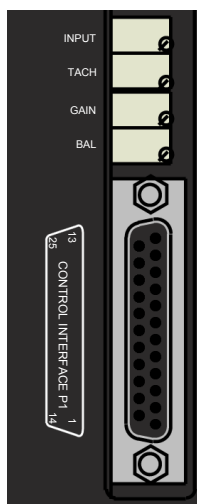
### 1.4.3. Potentiometers (POTs)

Potentiometers **INPUT**, **TACH**, **GAIN**, and **BALance** are associated with the pre-amplifier circuit contained in the amplifier. Refer to Figure 1-3 for location of the pots on the BA drive. These potentiometers are used to adjust the pre-amplifier gain when the **MODE** switch is set for velocity control using an external DC tachometer or incremental encoder for velocity feedback. Refer to Table 1-3 for pot functions.

**Table 1-3. Potentiometer Functions**

| Potentiometer  | CW       | CCW      | Function                                                                                                 |
|----------------|----------|----------|----------------------------------------------------------------------------------------------------------|
| <b>GAIN</b>    | decrease | increase | This pot adjusts the velocity loop AC gain of the pre-amplifier <sup>1</sup> .                           |
| <b>INPUT</b>   | increase | decrease | This pot adjusts the DC gain of the input command present at P1 Pins 8 & 21.                             |
| <b>TACH</b>    | increase | decrease | This pot adjusts the DC gain of the tach or encoder derived velocity feedback input present at P1-Pin 3. |
| <b>BALance</b> |          |          | Provides the means of canceling small DC offsets that may be present in the pre-amplifier circuit.       |

<sup>1</sup>Velocity loop GAIN adjustment is affected by current limit peak (switches 1 to 4). Maximum gain when 1 to 4 is closed.



### 1.4.4. Connector P1 and Enable Indicator

Connector **P1** (25-pin “D” type, female) provides the interface for input and output control connections. Refer to Table 1-4 for connector P1 pinouts. The LED **ENABLE** indicator will illuminate at all times until there is a fault or external shutdown, then the indicator will be off and motor power will be removed. Refer to Figure 1-3 for location of these items. The **POWER** LED will be green whenever +5V is present.

The **FAULT** LED energizes whenever there is a short circuit, current overload, thermal overload, etc., present on the drive. The unit must be powered down to clear the fault. In addition, the **OVERLOAD** LED energizes whenever the RMS current limit threshold is exceeded. If the RMS threshold is exceeded for more than two seconds, the drive becomes faulted and shuts down.

Table 1-4. Connector P1 Pinouts

| Pin #  | Input or Output         | Signal   | Function                                                                                                                                                                                                                                                                                               |
|--------|-------------------------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pin 1  | shield                  | ground   | Connection point to earth ground. Used for reducing electrical noise in control and feedback signals. Typically connected to the foil shield of a shielded cable.                                                                                                                                      |
| Pin 2  | output                  | power    | On board 5V power supply. Pin 2 is intended for powering an encoder and can supply up to 250mA of current.                                                                                                                                                                                             |
| Pin 3  | input                   | +tach    | Tachometer input for velocity feedback, (encoder vs. tach velocity feedback is jumper selectable). A tachometer may be used in the velocity loop configuration to provide negative feedback to the amplifier. This allows the amplifier to close the servo loop and control the stability of the loop. |
| Pin 4  | input <sup>(1)(2)</sup> | Hall A   | Hall effect A. One of three commutation signals used with brushless motors. Used in conjunction with Hall effect B and Hall effect C to provide motor rotor position information to the amplifier.                                                                                                     |
| Pin 5  | input <sup>(1)</sup>    | cosine   | Cosine signal from encoder. Optionally used, in conjunction with sine for deriving an electronic tachometer signal. Line receiver input                                                                                                                                                                |
| Pin 6  | input                   | cosine-N | Compliment of cosine (P1 - 5). Line receiver input.                                                                                                                                                                                                                                                    |
| Pin 7  | input                   | ground   | Signal common. Electrical reference for all control circuitry on amplifier.                                                                                                                                                                                                                            |
| Pin 8  | input <sup>(3)</sup>    | +input   | Non-inverting input of differential input circuit. A positive voltage on this input causes CCW motor rotation (torque or velocity mode). For single ended operation, connect command to the input and ground (Pin 21 of P1).                                                                           |
| Pin 9  | input <sup>(3)</sup>    | icmda    | Current command A. Jumper selectable current command input. Bypasses differential input, pre-amplifier, and self commutation circuit.                                                                                                                                                                  |
| Pin 10 | input <sup>(1)</sup>    | shutdown | Jumper selectable active high or active low input. Used to shut off power stage and therefore remove all power to the motor.                                                                                                                                                                           |
| Pin 11 | input <sup>(1)</sup>    | +ilmt    | Directional current limit input. When pulled to its active state, motion in the positive direction (CW motor shaft rotation) is inhibited (jumper selectable).                                                                                                                                         |
| Pin 12 | output                  | -fdbk    | Current feedback monitor. When running a brushless motor, this signal represents the current in motor phase A. When running a brush motor; this signal represents the entire motor current. Scaling is as follows:<br>BA50 8.3 Amp/V<br>BA75 12.5 Amp/V<br>BA100 16.6 Amp/V                            |
| Pin 13 | NC                      |          |                                                                                                                                                                                                                                                                                                        |
| Pin 14 | signal common           | ground   | Electrical reference for all control circuitry on amplifier. This pin is intended to be used as the connection point for the signal common of an encoder. (Used in conjunction with Pin 2 as the power supply connections to an encoder.)                                                              |
| Pin 15 | input                   | -tach    | Recommended reference input for tachometer. This point is identical to signal common.                                                                                                                                                                                                                  |
| Pin 16 | input <sup>(1)(2)</sup> | Hall B   | Hall effect B. One of three commutation signals used with brushless motors. Used in conjunction with Hall effect A and Hall effect C.                                                                                                                                                                  |

**Table 1-4. Connector P1 Pinouts (Cont'd)**

| Pin #  | Input or Output      | Signal | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------|----------------------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pin 17 | input <sup>(1)</sup> | Hall C | Hall effect C. One of three commutation signals used with brushless motors. Used in conjunction with Hall effect A and Hall effect B.                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Pin 18 | input <sup>(1)</sup> | sine   | Sine signal from encoder. Optionally used, in conjunction with cosine for deriving an electronic tachometer signal. Line receiver input.                                                                                                                                                                                                                                                                                                                                                                                                                |
| Pin 19 | input                | sine-N | Compliment of sine (P1- 18). Line receiver input.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Pin 20 | output               | power  | 5V on board 5V power supply.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Pin 21 | input <sup>(3)</sup> | -input | Inverting input of differential input circuit. A positive voltage on this input causes CW motor rotation (torque or velocity mode). For single ended command operation, ground this connection and connect signal to Pin 8 of P1.                                                                                                                                                                                                                                                                                                                       |
| Pin 22 | Input <sup>(3)</sup> | icmdb  | Current command B. Jumper selectable current command input. Bypasses differential input, pre-amplifier, and self commutation.                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Pin 23 | output               | -fault | Jumper selectable active high or active low (open collector) output. Used to indicate the status of the power stage (amplifier enabled or faulted).                                                                                                                                                                                                                                                                                                                                                                                                     |
| Pin 24 | input <sup>(1)</sup> | -ilmt  | Directional current limit input. When pulled to its active state, motion in the negative direction (CCW motor shaft rotation) is inhibited (jumper selectable).                                                                                                                                                                                                                                                                                                                                                                                         |
| Pin 25 | output               | -icmd  | <p>Preamplifier current command monitor. Used to monitor the output of the preamplifier circuit when in current command or velocity command mode. This signal can be used in conjunction with the peak current limiting switch (SW1-1 through SW1-4) to determine the actual output current. When switches SW1-1 -- SW1-4 are closed this signal has the following gain:</p> <p>BA50: 9.0 Amp/Volt<br/> BA75: 13.6 Amp/Volt<br/> BA100: 18.0 Amp/Volt</p> <p>Please see the DIP switch function description in Section 1.4.2. for more information.</p> |

1. Denotes input pull up to internal +5 V through a 10K resistor.
2. Denotes a factory option for analog Hall commutation is available. When using analog Hall feedback, only Hall A and Hall B connections are used.
3. Denotes that pins 21, 9, 22, and 8 also function as differential inputs for phase A and phase B current commands, respectively (this is a factory option).

### 1.4.5. I/O Circuitry

The following shows the internal circuitry for the BA amplifier. Note that all of the logic inputs can tolerate +24VDC.

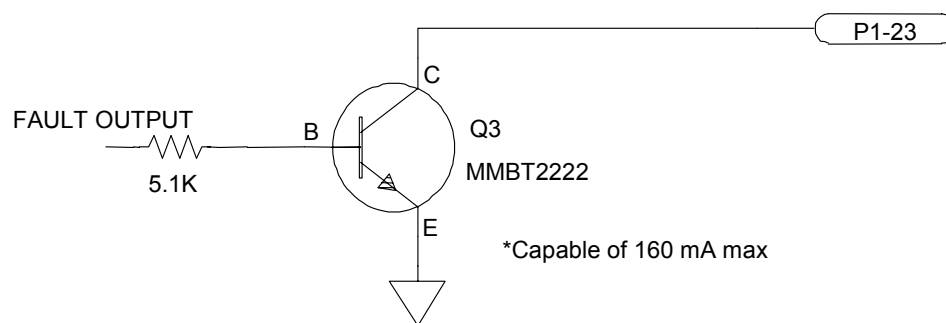


**Figure 1-4. Fault Output**

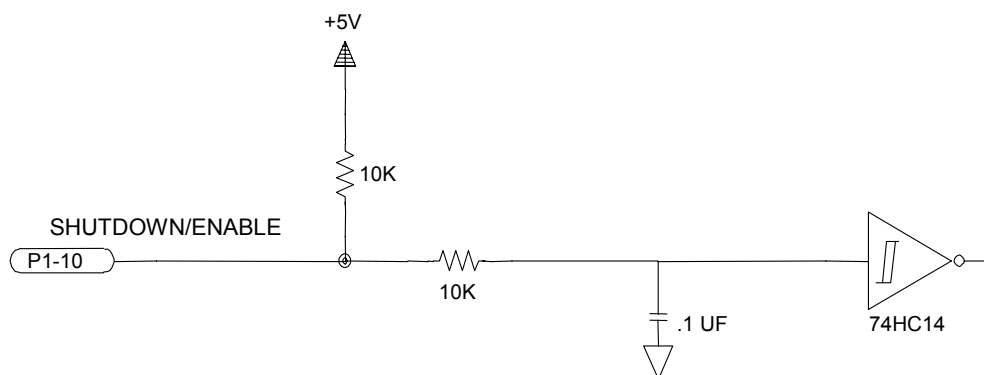


**Figure 1-5. Enable/Shutdown Inputs**

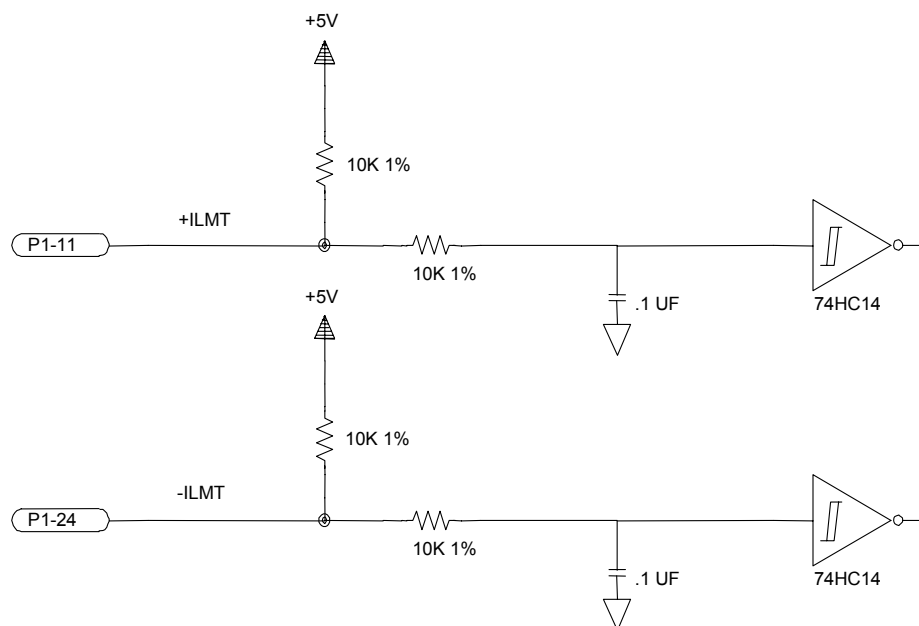
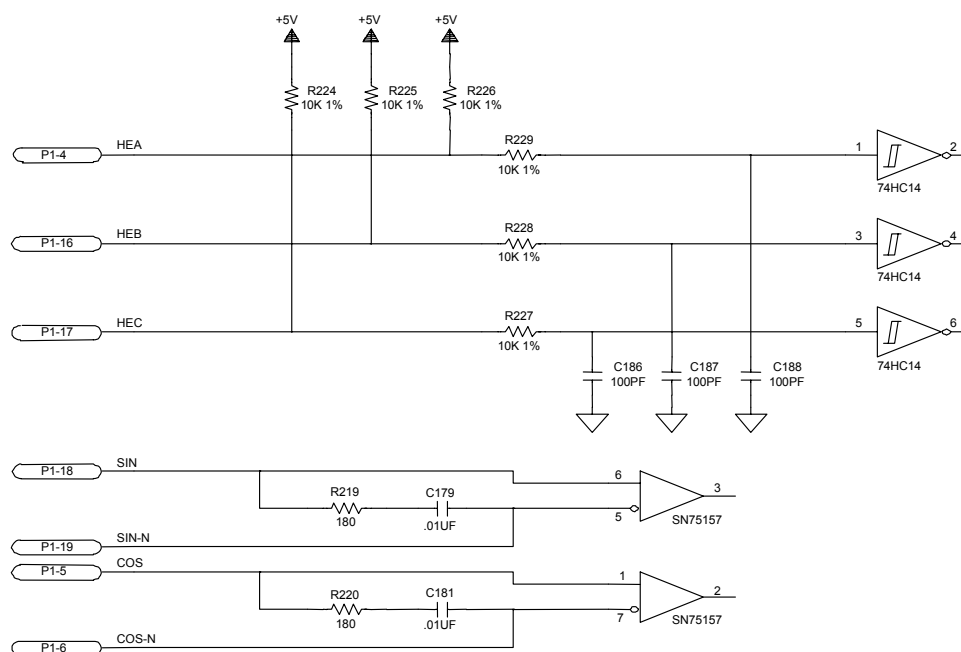
Figure 1-6.  $\pm$  Limit Inputs

Figure 1-7. Hall and Encoder Inputs

## 1.5. Safety Procedures and Warnings

The following statements apply wherever the Warning or Danger symbol appears within this manual. Failure to observe these precautions could result in serious injury to those performing the procedures and/or damage to the equipment.

If the equipment is used in a manner not specified by the manufacturer, the protection by the equipment may be impaired. The user should practice caution when following the given procedures. Deviation from this may result in damage to the equipment or machinery.



Hazardous voltages are present up to eight minutes after power is disconnected.



Motor Temperature may exceed 50°C.



Motors must be mechanically secure before applying power.



Amplifier case/heatsink temperatures may exceed 50°C.



To minimize the possibility of electrical shock and bodily injury, ensure that the motor is decoupled from the mechanical system and/or disconnected from the amplifier when servicing the system.



To minimize the possibility of electrical shock and bodily injury when any electrical circuit is in use, ensure that no person is exposed to the circuitry.



To minimize the possibility of bodily injury, make certain that all electrical power switches (all switches external to the amplifier) are in the off position prior to making any mechanical adjustments.





CHAPTER 2: INSTALLATION AND OPERATION

|                                                     |      |
|-----------------------------------------------------|------|
| <b>In This Section:</b>                             |      |
| • Jumper Selections .....                           | 2-1  |
| • Wiring, Grounding, and Shielding Techniques ..... | 2-4  |
| • Integrated Configurations .....                   | 2-7  |
| • Control Connections .....                         | 2-10 |
| • Motor Phasing Process .....                       | 2-13 |
| • Current Regulator Adjustment .....                | 2-15 |

2.1. Jumper Selections

The BA series amplifiers are jumper selectable providing the user with quick reconfiguration capability of operating modes. Table 2-1 lists the jumpers and the default configurations for the amplifiers. Figure 2-1 highlights where the jumpers are located on the board (with the default configurations).

Table 2-1. Jumper Selections

| Jumpers | Positions | Function                                                                                                                                                                           |
|---------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| JP3     | 1-2       | Selects brushless mode of operation. (default).                                                                                                                                    |
|         | 2-3       | Selects brush mode operation.                                                                                                                                                      |
| JP4     | 1-2       | Active high shutdown input. Logic high on P1-10 shuts off power stage. (default).                                                                                                  |
|         | 2-3       | Active low shutdown input. Logic low (0V) on P1-10 shuts off power stage.                                                                                                          |
| JP5     | 1-2       | Selects brushless mode operation. (default).                                                                                                                                       |
|         | 2-3       | Selects brush mode operation.                                                                                                                                                      |
| JP6     | 1-2       | Selects brushless mode of operation. (default).                                                                                                                                    |
|         | 2-3       | Selects brush mode operation.                                                                                                                                                      |
| JP8     | 1-2       | 0° commutation offset (default).                                                                                                                                                   |
|         | 2-3       | 30° offset.                                                                                                                                                                        |
| JP9     | 1-2       | Active low +ILMT. Logic low on P1-11 stops CW (+) motor movement. (default).                                                                                                       |
|         | 2-3       | Active high +ILMT. Logic (5V) on P1-11 stops CW (+) motor movement.                                                                                                                |
| JP10    | 1-2       | Active low -ILMT. Logic low on P1-24 stops CCW (-) motor movement. (default).                                                                                                      |
|         | 2-3       | Active high -ILMT. Logic high (5V) on P1-24 stops CCW (-) motor movement.                                                                                                          |
| JP11    | 1-2       | Power stage drive signal (phase A) is derived from differential pre-amp input. BA drive performs self-commutation. (default).                                                      |
|         | 3-4       | Power stage drive signals are derived from input signal at P1-9. Controller must perform commutation.                                                                              |
|         | 5-6       | Power stage drive signals are derived from A phase analog Hall (factory option).                                                                                                   |
|         | 7-8       | Power stage drive signals are derived from A phase differential input (factory option).                                                                                            |
| JP12    | 2-3       | Active low fault output. Open collector output P1-23 pulls to a logic low to indicate a drive fault.                                                                               |
|         | 1-2       | Active high fault output. Open collector output P1-23 sets to a high impedance state (must be pulled to a logic high by an external resistor) to indicate a drive fault (default). |
| JP13    | 1-2       | Power stage drive signal (phase B) is derived from differential pre-amp input. Drive performs self-commutation. (default).                                                         |
|         | 3-4       | Power stage drive signals are derived from input signal at P1-22. Controller must perform commutation.                                                                             |
|         | 5-6       | Power stage drive signals are derived from B phase analog Hall (factory option).                                                                                                   |
|         | 7-8       | Power stage drive signals are derived from B phase differential input (factory option).                                                                                            |
| JP14    | 2-3       | Current command configuration or tachometer feedback through pin 3 of P1 in the velocity loop configuration (default).                                                             |
|         | 1-2       | Electronic tachometer signal derived from encoder signals in velocity loop configuration.                                                                                          |
| JP15    | 1-2       | Selects brushless mode operation (default).                                                                                                                                        |
|         | 2-3       | Selects brush mode operation.                                                                                                                                                      |
| JP22    | 1-2       | Signal common of control section connected to earth ground (default).                                                                                                              |
|         | 2-3       | Signal common, not referenced to earth ground.                                                                                                                                     |
| JP25    | 1-2       | 0° commutation offset (default).                                                                                                                                                   |
|         | 2-3       | 30° commutation offset.                                                                                                                                                            |
| JP26    | 1-2       | 0° commutation offset (default).                                                                                                                                                   |
|         | 2-3       | 30° commutation offset.                                                                                                                                                            |

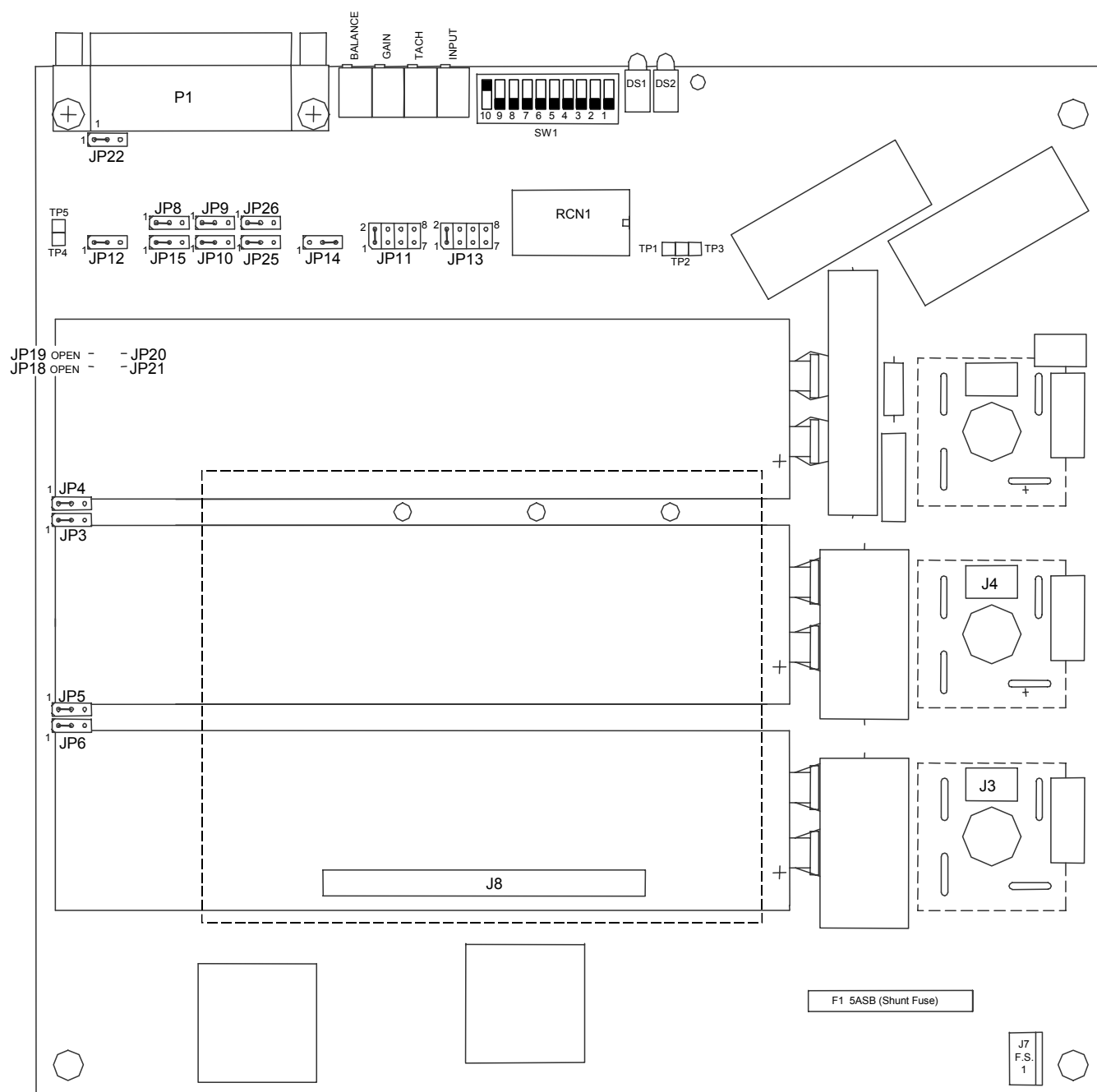


Figure 2-1. BA50/75/100 Board Assembly (Jumpers Shown in Default)

## **2.2. Wiring, Grounding, and Shielding Techniques**

AC power wires (AC1, AC2, AC3) and the protective ground wire should be 12 AWG size wire. An external 30-amp maximum fuse or breaker is required on the AC power inputs for the BA75 and BA100. A 25-amp max. fuse or breaker should be used for the BA50. The motor outputs should be connected with the #10 AWG wire. The motor protective ground should not be less than 14 AWG wire.

To reduce electrical noise in the BA Series amplifiers, the user should observe the motor and input power wiring techniques explained in the following sections.

### **2.2.1. Minimizing EMI Interference**

The BA Series are high efficiency PWM amplifiers operating at a 20K Hz switching rate.

The switching time between positive and negative rails on each of the motor leads is less than 50 nano-seconds for a 320 VDC bus. This switching rate can generate Electromagnetic Interference (EMI) into the MHz band. To minimize this EMI, it is recommended that the motor leads be twisted together with the motor cable grounding wire and surrounded with a foil shield. Refer to Figure 2-2.

In addition to the EMI effects, electro-static (capacitive) coupling to the motor frame is very high requiring the frame to be grounded in order to eliminate a shock hazard. Additional electro-static coupling exists between the three twisted motor leads and the foil shield of the motor cable.

This coupling forces high frequency currents to flow through the returning earth ground of the motor cable. To minimize this problem and maintain low levels of EMI radiation, perform the following.

1. Use shielded cable to carry the motor current and tie the shield to earth ground. Refer to Figure 2-2.
2. Place one toriod (ferrite) around the three motor leads (two leads for brush motors). The toriod should have seven turns for 10 AWG wire. This helps reduce the harmonics generated by the 20 KHz switching waveform.
3. Use a cable with sufficient insulation. This will reduce the capacitive coupling between the leads that, in turn, reduces the current generated in the shield wire.
4. Provide strong earth ground connections to the amplifier, additional heat sink, and the motor. Offering electrical noise a low impedance path to earth ground not only reduces radiated emissions, but also improves system performance.
5. If possible, do not route motor cables near cables carrying logic signals and use shielded cable to carry logic signals.

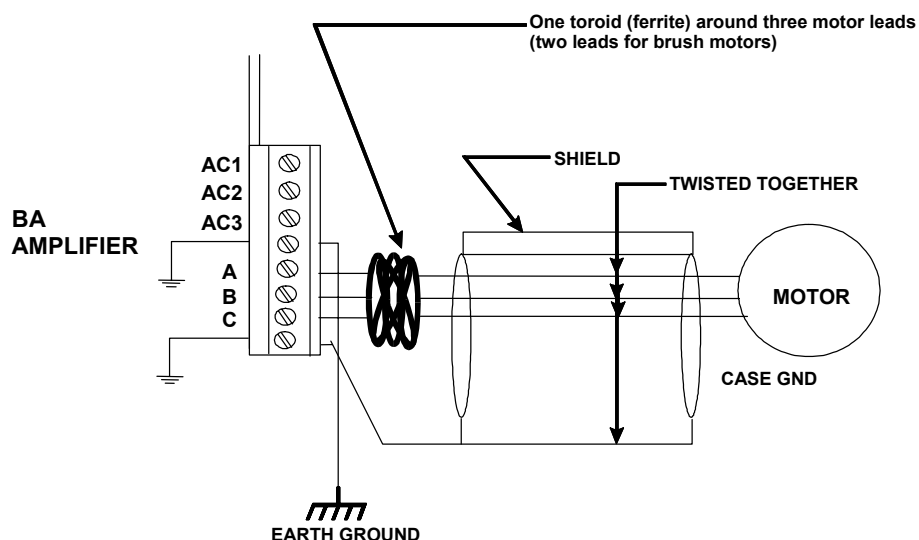


Figure 2-2. Wiring to Minimize EMI and Capacitive Coupling

### 2.2.2. Minimizing 50/60 HZ Line Interference

Operating the BA series amplifiers from an off-line source of 115 VAC or 230 VAC creates some additional problems.

First, there is a potential problem of EMI generated from the switching power stage of the BA amplifier propagating through the bridge rectifier and out through the AC1, AC2 and AC3 input AC line connections. Back-propagation of noise into the AC lines can be minimized using a line filter. An example of such a filter and proper connection to the BA amplifier is shown in Figure 2-3.

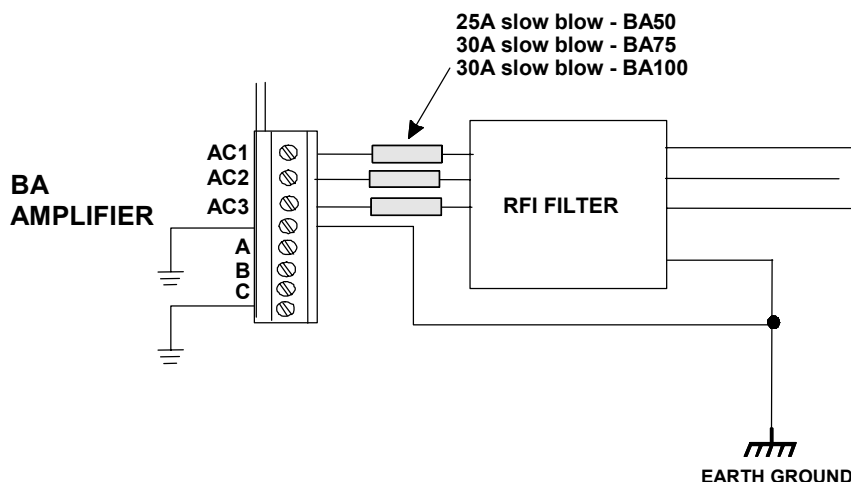


Figure 2-3. Back-Propagation Line Filter Connection

Another problem that potentially exists with off line connections is 50/60 Hz electrostatic coupling between the frame of the AC motor and the **AC1**, **AC2**, and **AC3** AC input power. If a single-phase supply is used where one side of the phase is referenced to ground, the DC bus of the amplifier “swings” at 50/60 Hz with respect to the motor frame.

The path of current caused by this coupling between the motor frame and the amplifier stage passes through the current feedback sensing devices of the amplifier. Depending on the magnitude of this current, a 50/60 Hz torque disturbance may be present in the position loop.

To eliminate this problem, an isolation transformer can be used to block the 50/60 Hz from being seen by the motor frame. Refer to Figure 2-4 for connection of this transformer.

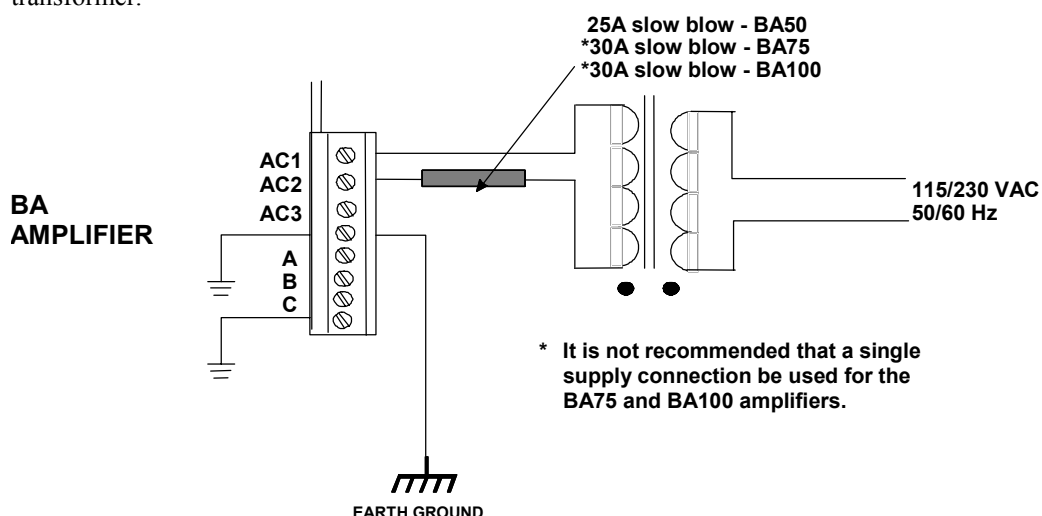


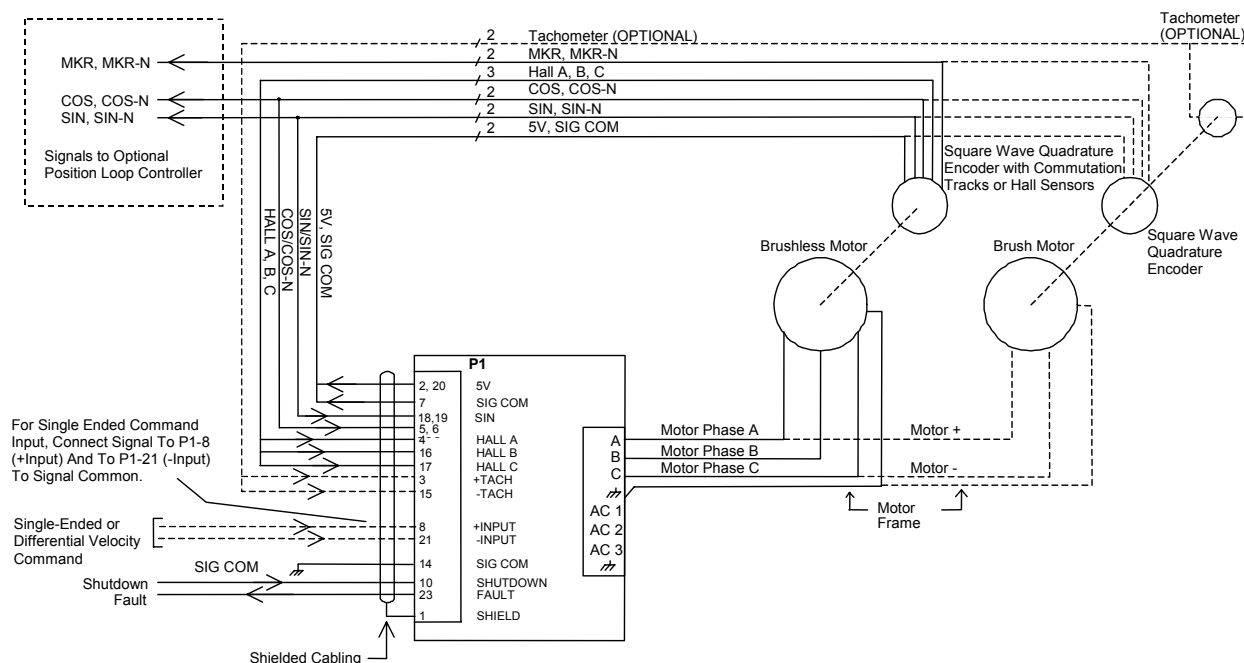
**Figure 2-4. Isolation Transformer Connection (eliminates torque disturbance)**

### 2.3. Integrated Configurations

The BA amplifiers can be integrated into a system using three basic configurations; velocity command, current command, and dual-phase command. Each of these has their advantages and disadvantages depending upon the user's specific needs.

### 2.3.1. Velocity Command Configuration

In the velocity command configuration, the speed of the motor is controlled by the amplifier. A feedback signal from either a DC tachometer or an incremental encoder is monitored by the amplifier. From this signal, the amplifier adjusts the velocity of the motor accordingly depending upon the velocity command from the external controller. In this configuration the amplifier closes and controls the velocity loop. The velocity command configuration is shown in Figure 2-5. This configuration can drive both brush and brushless DC motors.



### Figure 2-5. Velocity Command Configuration

### 2.3.2. Current Command Configuration

In this configuration, the output current to the motor is proportional to the current command input. The current command configuration is shown in Figure 2-6. The advantage to this configuration is the sine and cosine signals to the amplifier and a tachometer are not required. This configuration will also drive both brush and brushless DC motors.

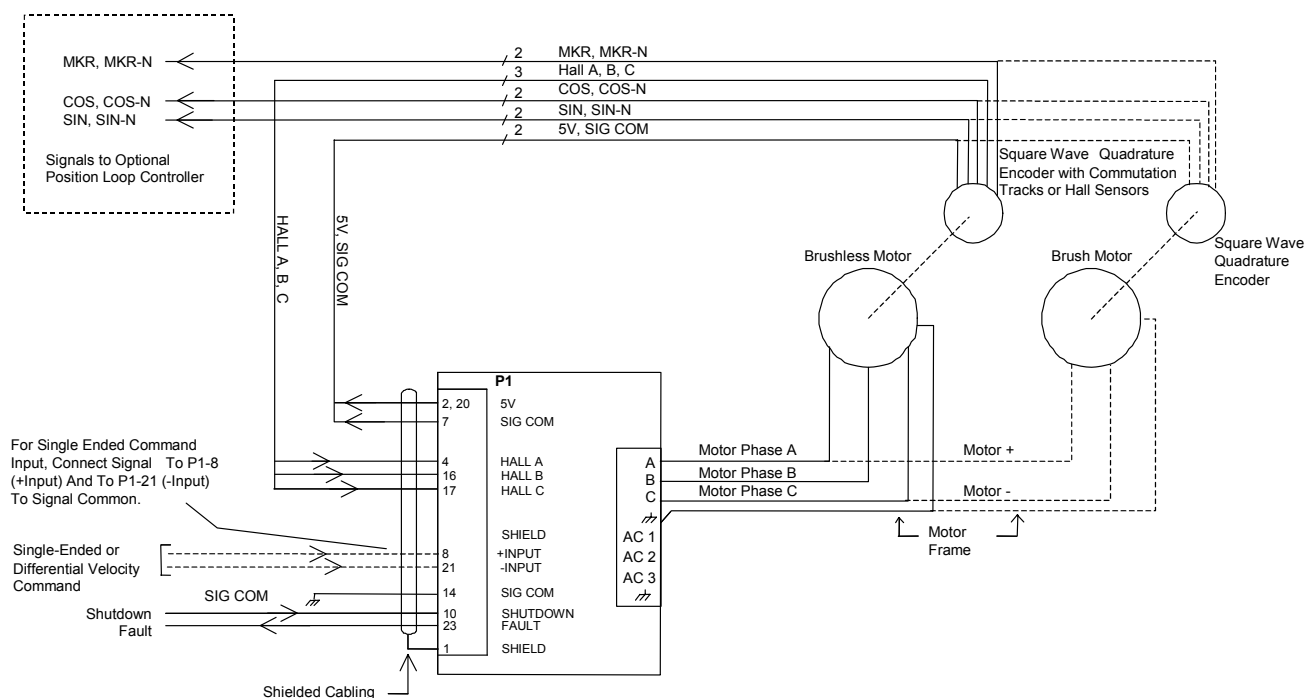


**Figure 2-6. Current Command Configuration**

### 2.3.3. Dual-Phase Command Configuration

This mode is used with a brushless motor only. In this configuration, the differential input, pre-amplifier, and self-commutation circuits are bypassed. The dual-phase inputs are sinusoidal and are 120° out of phase from each other. The third phase is generated by the amplifier. The dual-phase command configuration is shown in Figure 2-7. The advantage to this configuration is that it provides the smoothest possible motion.

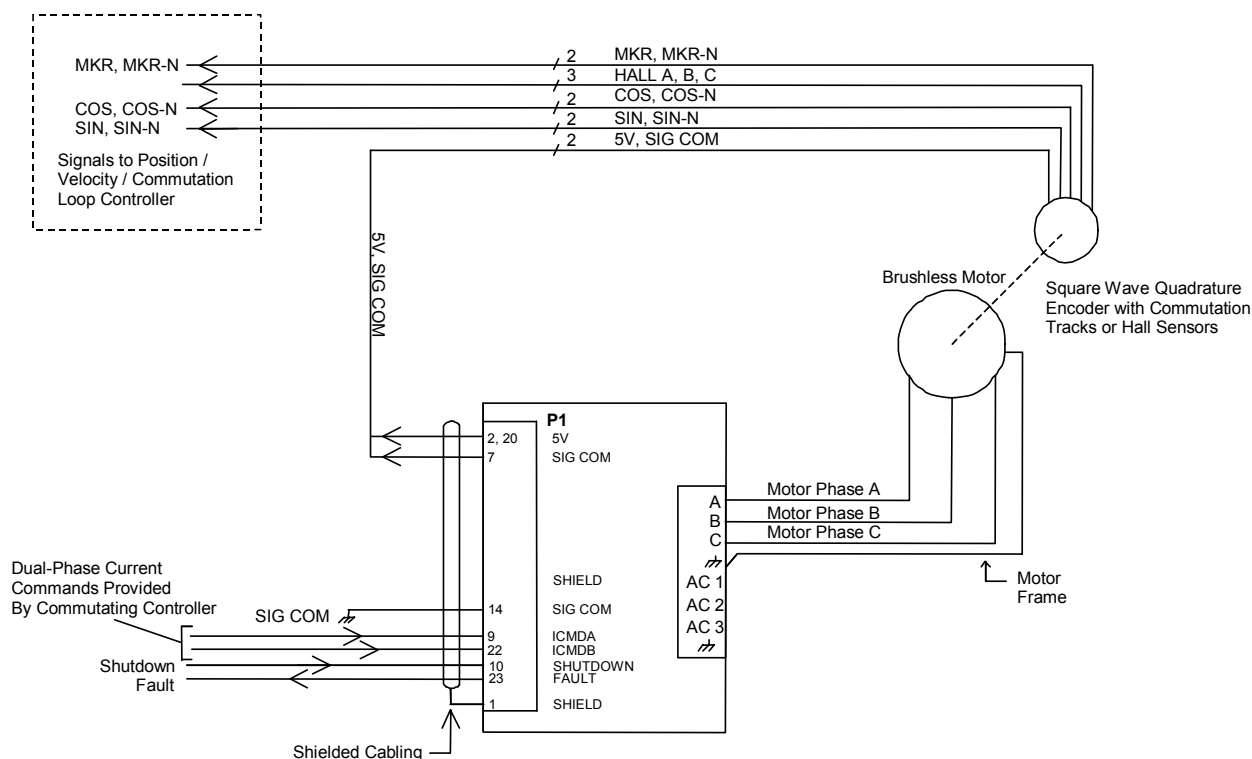


Figure 2-7. Dual-Phase Command Configuration

## 2.4. Control Connections

The BA drives can be wired into a system in one of two ways depending upon the desired mode of operation. Command signals can be referenced to velocity or torque (current) control signals. The user has access to four potentiometers, three that adjust gain while the fourth (BALance) compensates for input signal offsets. Figure 2-8 illustrates a portion of the pre-amplifier circuit that is accessible to the user for adjusting command signal gains.



For adjustments in gain roll-off, "Personality Module" **RCN1**, pins 7-10 and 8-9 are provided for the selection of the appropriate resistor/capacitor pair (factory default values are shown in Figure 2-8).

### 2.4.1. Setup - Torque Command Mode (Current)

To setup the pre-amplifier circuit for use in the torque (current command) mode, configure the BA amplifier as follows:

- Place SW1 position 10 (mode) to closed (**default**)
- Place SW1 position 9 (test) to open (**default**)
- SW1 positions 1 through 4 selects current limit, positions 5 through 8 selects RMS limit
- Potentiometers "INPUT" set full CW and "GAIN" set full CCW to provide a transconductance gain of  $\pm 10$  volts for full current output. "BALance" and "TACH" have no effect.
- JP14 set to 2-3 (**default**)
- JP11 and JP13 set to 1-2 (**default**)
- JP3, JP5, JP15, and JP6 set to 1-2 (**default**) for brushless motor operation or 2-3 for brush motor operation

With this configuration, an input signal of  $\pm 10$  volts to pins +**INPUT** with respect to -**INPUT** will produce the maximum current output signal (viewed at P1 pin 25 **ICMD**) of  $\pm 5.5$  volts. Switches "SW1" 1 through 4 are used to scale this  $\pm 5.5$  volt signal from zero to maximum current. Refer to Figure 2-6 for torque command configuration.

### 2.4.2. Setup - Velocity Command Mode

For this mode, a velocity feedback signal is required. This feedback signal can be derived from two sources. From an analog DC tachometer that is connected to the +**TACH** pin or from an incremental encoder that is connected to the sine and cosine pins (Refer to Figure 2-5). To setup the pre-amplifier circuit for use in the velocity command mode, configure the BA amplifier as follows:

- Place SW1 position 10 (mode) to open
- Place SW1 position 9 (test) to open (**default**)
- SW1 positions 1 through 4 selects current limit, positions 5 through 8 selects RMS limit
- Potentiometers "INPUT", "GAIN", "BALance", and "TACH" adjust pre-amplifier gain and offset.

For most applications under the velocity command mode, the preferred starting point for setting the three gain pots is as follows:

**INPUT** pot - 1/3 CW from full CCW

**TACH** pot - full CW

**GAIN** pot - full CW

These initial settings will usually generate a stable system if it is assumed that the tach feedback gain is around 3 volts/Krpm, or if an encoder is used and the line resolution is between 1,000 and 1,500 per revolution.



- JP14 set to 1-2 for encoder or 2-3 **(default)** for tachometer velocity feedback
- JP11 and JP13 set to 1-2 **(default)**
- JP3, JP5, JP15, and JP6 set to 1-2 **(default)** for brushless motor operation or 2-3 for brush motor operation

**NOTE:** For single ended command input, connect signal to P1-8 (+input) and the P1-21 (-Input) to signal common.

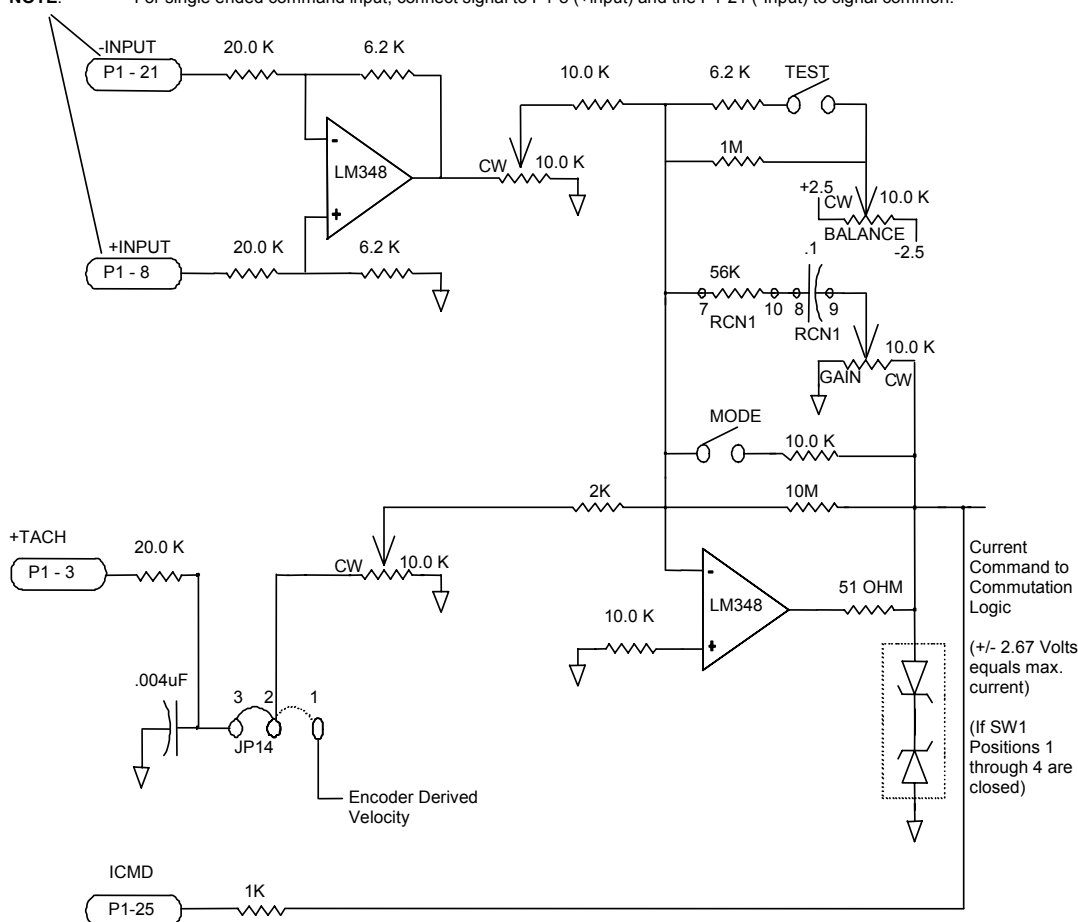


**Figure 2-8. Command Signal Adjustment Portion of the Pre-Amplifier Circuit**



To minimize the possibility of electrical shock and bodily injury, ensure that the motor is decoupled from the mechanical system to avoid personal injury if the motor begins to spin.

Starting with a zero input command signal, apply power to the amplifier. If the motor spins uncontrollably, remove power and switch the polarity of the tach input signal. If an encoder is being used, switch the sine and cosine input signals. Verify compliment signals (sin & sin-N, cos & cos-N) are of correct phasing.

Again, apply power to the amplifier. If the motor begins to oscillate, turn the **TACH** pot CCW until the oscillation stops. The **GAIN** and **TACH** potentiometers can be adjusted to provide maximum stiffness on the motor shaft.



If the desired stiffness is unattainable, the components connected to personality module **RCN1** pins 8-9 and 7-10 may be need to be changed.

The **BALance** pot is used to cancel any bias in the internal or external control circuit that would cause the motor to rotate when the input command signal is zero.

If the **TEST** switch is closed, the effects of the **BALance** pot are greatly magnified. This is useful when a test bias signal is desired (for velocity or torque modes) to be applied to the amplifier without introducing an external command signal.

### 2.4.3. Setup - Dual-Phase Command Mode

To setup the pre-amplifier circuit for use in the dual-phase mode, configure the BA amplifier as follows:

- JP11 and JP13 are set to 3-4
- JP3, JP5, JP15, and JP6 are set to 1-2 (**default**).

This mode is used with brushless motors only. Refer to Figure 2-7 for dual-phase command configuration.

## 2.5. Motor Phasing Process

When configuring the BA amplifier to run a brushless motor, the commutation signal input connections (labeled HALL A, B, C on connector P1 pins 4, 16, and 17) are necessary. These sequences and the generated output motor phase voltages (motor output connections A, B, and C) are shown in Figure 2-9. The voltages generated are made under the conditions of a positive signal placed at **+INPUT** with respect to **-INPUT** at control signal input/output connector P1. A “0” for the given HALL input indicates zero voltage or logic low, where a “1” indicates five volts or logic high.

If an Aerotech brushless motor is used with the BA amplifier, motor phase and HALL connections can be easily determined by referring to the system interconnection drawings in Figure 2-5, Figure 2-6, and Figure 2-7. Also, refer to the figures in Appendix C.



### 2.5.1. Determining Phase/Hall Sequence

For a motor with an unknown phase/hall sequence, a simple test can be performed on the motor to determine the proper connections to the BA amplifier.

Before performing the following steps, ensure that the motor leads are completely disconnected from the amplifier.



The tests outlined below do not require that the amplifier be turned on since Figure 2-9 illustrates the generated output voltage of the motor relative to the input Hall sequences.



The equipment needed for this test is a two-channel oscilloscope and three resistors (typically 10K ohm, 1/2 watt) wired in a “Wye” configuration.

Connect the ends of the three resistors to motor terminals A, B, C. Use one channel of the oscilloscope to monitor motor terminal A with respect to the “Wye” neutral (e.g., the point where all three resistors are connected together). Turn the shaft of the motor CCW and note the generated voltage. This voltage represents the “phase A to neutral” CEMF. With the second oscilloscope probe, determine the Hall switch that is “in phase” with this voltage. Similarly, phase B and C should be aligned with the other two Hall switches.

Refer to Figure 2-9 and note the generated output voltages of the amplifier relative to the Hall sequences applied to **HALL A**, **HALL B**, and **HALL C** connections at connector **P1**. For proper operation, the CEMF generated motor phase voltages should be aligned to the amplifier's output generated voltage with the given Hall effect sequence shown in Figure 2-9.

If the sequence of Hall signals relative to the generated motor voltage (e.g. motor CEMF) is adhered to as illustrated in Figure 2-9; a positive (+) voltage signal applied to pin 8 (+INPUT) of connector P1 relative to pin 21 (-INPUT) of P1 or pin 19 (signal common) of P1 will produce a CCW (e.g., a negative rotation) rotation of the motor shaft as viewed from the front of the motor.

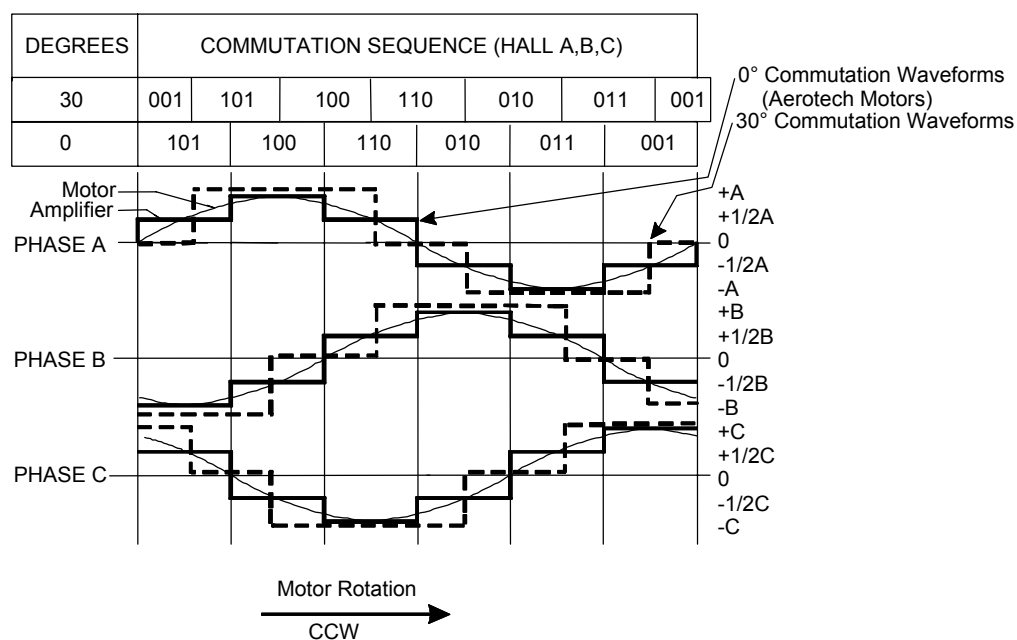


**Figure 2-9. Motor Phasing**

## 2.6. Current Regulator Adjustment

The three-phase current regulator circuit is illustrated in Figure 2-10. Details to this circuit, like the “Pre-amplifier” circuit described in the previous section, are provided so that the user may optimize gains.

The BA amplifier provides three independent current regulator circuits, one for each phase of the AC brushless motor (for DC brush motors, only “Phase A” regulator is used). Regulators “A” and “B” are each provided with a current command from either the internal “six step” commutation circuit or an external current command input (**ICMDA** and **ICMDB**), depending on the settings of JP11 and JP13.

Two internally isolated circuits, one for phase “A” and the other for phase “B”, provide the motor current feedback signals.

The two current command signals as well as the two current feedback signals are each summed with the result providing the current command and current feedback signals for phase “C”.

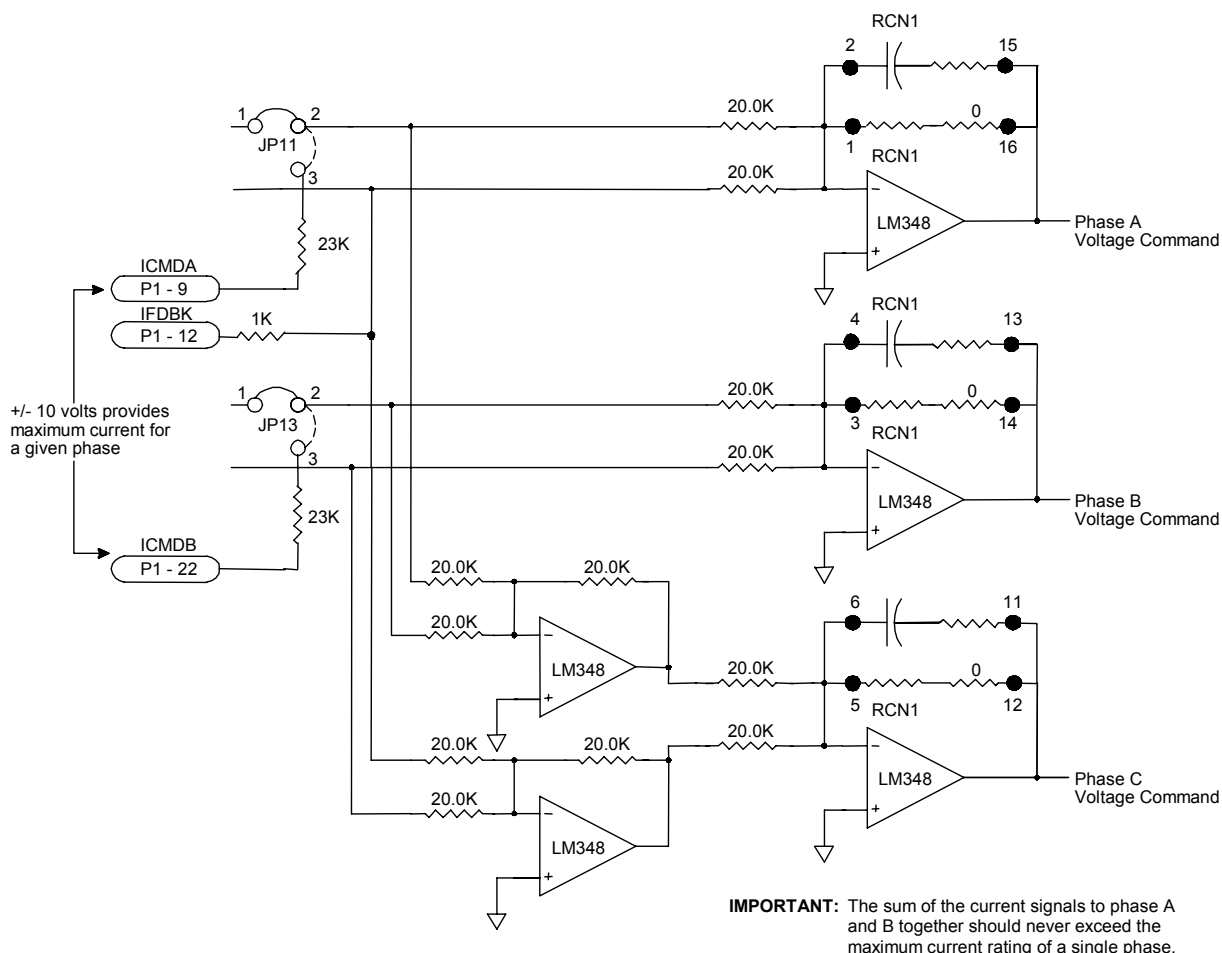


Figure 2-10. Three-Phase Current Regulator Circuit

Pins 1-18 and 2-17 “Personality Module” **RCN1** provide gain compensation for phase “A” regulator circuit. Similar compensation is provided for phase “B” and “C” circuits as shown in Figure 2-10. The default values for these selectable components (RCN1) are shown in Figure 2-10.

Connection **IFDBK** (pin 12 of P1) is provided for monitoring phase “A” current. For AC brushless motor operation, the signal at this pin would represent motor phase “A” current. For DC brush motor operation, this signal would represent the current flowing in the motor armature. The scale factor for current feedback on P1-12 is 16.6 Amp/Volt for the BA100, 12.5Amp/Volt for the BA75, and 8.3Amp/Volt for the BA50.

▽ ▽ ▽

## CHAPTER 3: TECHNICAL DETAILS

### In This Section:

- Part Number and Ordering Information ..... 3-1
- Electrical/Environmental Specifications ..... 3-2
- BA Amplifier Dimensions ..... 3-6

### 3.1. Part Number and Ordering Information

Ordering information regarding part numbers, models, and packages is shown below in Table 3-1.

**Table 3-1. Ordering Information**

| Amplifier Series | Output Current, Peak                                                                          | Operating Bus Voltage | Internal Shunt Power Resistor |
|------------------|-----------------------------------------------------------------------------------------------|-----------------------|-------------------------------|
| BA               | 50, 75, 100                                                                                   | 320 = 230 VAC input   | S = Shunt regulator           |
| Bus Voltage      |                                                                                               |                       |                               |
| - 320            | 320 VDC bus; 230 VAC input, direct line operation (w/ shunt regulator)                        |                       |                               |
| Options          |                                                                                               |                       |                               |
| - S              | Shunt regulator                                                                               |                       |                               |
| Examples         |                                                                                               |                       |                               |
| BA50-320-S       | 25 A cont., 50 A peak servo amplifier/power supply, w/shunt regulator 230VAC, 1 phase input   |                       |                               |
| BA75-320-S       | 37 A cont., 75 A peak servo amplifier/power supply, w/shunt regulator 230VAC, 3 phase input   |                       |                               |
| BA100-320-S      | 50 A cont., 100 A peak servo amplifier/power supply, w/shunt regulator 230VAC, 3 phase input  |                       |                               |
| Accessories      |                                                                                               |                       |                               |
| TV0.3-28         | 0.3 kVA autotransformer; 28 or 56 VAC out for 40 or 80 VDC bus, 115/230 VAC, 50/60 Hz input   |                       |                               |
| TV0.3-56         | 0.3 kVA autotransformer; 56 or 115 VAC out for 80 or 160 VDC bus, 115/230 VAC, 50/60 Hz input |                       |                               |
| TV1.5            | 1.5 kVA isolation transformer; 115/230 VAC input; 28, 43, 56, 70, 115 VAC output              |                       |                               |
| TV2.5            | 2.5 kVA isolation transformer; 115/230 VAC input; 28, 43, 56, 70, 115 VAC output              |                       |                               |
| TV5              | 5 kVA isolation transformer; 115/230 VAC input; 28, 43, 56, 70, 115 VAC output                |                       |                               |
| TB               | Screw terminal block for BA DB25 control connector                                            |                       |                               |
| LF               | AC Line Filter, general noise suppression (not for CE Compliance)                             |                       |                               |
| UFM              | AC Line Filter Module (required for BA amps to meet CE Compliance)                            |                       |                               |

### 3.2. Electrical/Environmental Specifications

The electrical and environmental specifications and connector P1 pinouts for all BA drive models are listed in Table 3-2.

**Table 3-2. Electrical Specifications**

| Model                                                                                                          | Units   | BA50                                      | BA75       | BA100      |
|----------------------------------------------------------------------------------------------------------------|---------|-------------------------------------------|------------|------------|
| Output Voltage <sup>(1)</sup>                                                                                  | VDC     | 40-320 <sup>(2)</sup>                     |            |            |
| Peak Output Current (2 sec)<br>(current rating based on amplifier<br>mounted to NEMA panel, see<br>Figure 3-2) | A(pk)   | 50                                        | 75         | 100        |
| Continuous Output Current<br>(current rating based on amplifier<br>mounted to NEMA panel, see<br>Figure 3-2)   | A(pk)   | 25                                        | 37         | 50         |
| Peak Power Output (includes AC<br>line droop)                                                                  | Watts   | 12,000                                    | 16,000     | 20,000     |
| Continuous Power Output<br>(includes AC line droop)                                                            | Watts   | 6,000                                     | 8,000      | 10,000     |
| Efficiency                                                                                                     | %       | 97                                        |            |            |
| Preamp Gain (max) (velocity<br>mode)                                                                           | dB      | 100                                       |            |            |
| Power Amplifier Gain (current<br>command mode)                                                                 | A/V     | 5                                         | 7.5        | 10         |
| Power Amplifier Bandwidth                                                                                      | kHz     | 2                                         |            |            |
| PWM Switching Frequency                                                                                        | kHz     | 20                                        |            |            |
| Minimum Load Inductance                                                                                        | mH      | 0.8 mH @ 160 VDC bus<br>(1.6 mH @320 VDC) |            |            |
| Maximum Shunt Regulator<br>Dissipation                                                                         | Watts   | 100                                       | 100        | 150        |
| Maximum Heat Sink Temperature                                                                                  | deg C°  | 65                                        |            |            |
| Operating Temperature                                                                                          | deg C°  | 0 to 50                                   |            |            |
| Storage Temperature                                                                                            | deg C°  | -30 to 85                                 |            |            |
| Weight                                                                                                         | lb (kg) | 8.5 (3.9)                                 | 10.6 (4.8) | 12.5 (5.7) |
| Installation Overvoltage category                                                                              |         | 2                                         |            |            |
| Pollution Degree                                                                                               |         | 2                                         |            |            |

Table 3-2. Electrical Specifications (Cont'd)

| Feature                                | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Modes of Operation (jumper selectable) | <p><b>Brushless:</b></p> <ul style="list-style-type: none"> <li>- single current command with on-board 6-step commutation from HED inputs.</li> <li>- dual phase commands with sinusoidal commutation provided by an external motion controller, third phase command is derived from the amplifier.</li> <li>- velocity command with 6-step commutation from HED inputs and velocity feedback from the tach or encoder.</li> <li>- analog Hall effect device (HED) supplied as a factory option</li> </ul> <p><b>Brush:</b></p> <ul style="list-style-type: none"> <li>- single current command.</li> <li>- velocity command with velocity feedback from the tach or encoder.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Command Inputs                         | <ul style="list-style-type: none"> <li>- <b>+input-Pin 8, -input-Pin 21:</b> Differential inputs for current or velocity commands, 0 to <math>\pm 10</math> VDC input. “+input” (non-Inverting input) can be used in single ended fashion. A positive voltage on this input causes CCW motor rotation. “-input” (inverting input) can be used in single ended fashion. A positive voltage on this input causes CW motor rotation.</li> <li>- <b>icmda-Pin 9, icmdb-Pin 22:</b> dual phase, <math>\pm 10</math>V input. ICMDA (current command A) and ICMDB (current command B) are jumper selectable current command inputs. They bypass the differential input, pre-amplifier, and self-commutation circuit. They are to be used with controllers that provide external velocity loop and commutation control.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Feedback Inputs                        | <ul style="list-style-type: none"> <li>- <b>Hall A-Pin 4, Hall B-Pin 16, Hall C-Pin 17:</b> Hall effect device inputs for commutation, 0 to 5 VDC, internal pull-up, and 10K input. Commutation signals used with brushless motors to provide motor rotation position information to the amplifier. This allows the amplifier to steer the three phases of the motor currents in such a fashion so as to provide rotation of the motor in the desired direction at the desired speed. TTL level input. (<b>Note:</b> analog Hall signals are connected at pin 4 and pin 16. Analog Hall commutation is a factory option).</li> <li>- <b>sine/sine-N-Pin 18, Pin 19, cosine/cosine-N-Pin 5, Pin 6:</b> Encoder inputs for velocity feedback, differential 0 to 5VDC TTL, internal pull-up, 10K input. Sine and cosine are optionally used in conjunction with one another for deriving an electronic tachometer signal.</li> <li>- <b>+tachometer-Pin 3:</b> Tachometer input for velocity feedback, (encoder vs. tach velocity feedback is jumper selectable). A tachometer may be used in the velocity loop configuration to provide negative feedback to the amplifier. This allows the amplifier to close the servo loop and control the stability of the loop.</li> <li>- <b>tachometer- Pin 15:</b> Reference input for tachometer. This point is identical to signal common.</li> </ul> |

Table 3-2. Electrical Specifications (Cont'd)

| Feature                 | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Logic Inputs            | <ul style="list-style-type: none"> <li>- <b>ilmt-Pin 24, +ilmt-Pin 11</b>: Directional current limit inputs (jumper selectable polarity). When “+ILMT” is pulled to its active state, motion in the positive direction (CW motor shaft rotation) is inhibited. When “-ILMT” is pulled to its active state, motion in the negative direction (CCW motor shaft rotation) is inhibited. TTL level input 0 to 5 VDC, internal pull-up, and 10K input.</li> <li>- <b>shutdown-Pin 10</b>: Jumper selectable active high or active low input. Used to shut off power stage and therefore remove all power to the motor. TTL level input 0 to 5 VDC, internal pull-up, and 10K input.</li> <li>- <b>signal ground-Pins 7 and 14</b>: Electrical reference for all control circuitry on amplifier.</li> <li>- <b>signal shield-Pin 1</b>: Connected internally to earth ground. Used for reducing electrical noise in control and feedback signals.</li> </ul> |
| Logic Outputs           | <ul style="list-style-type: none"> <li>- <b>fault-Pin 23</b>: Jumper selectable active high or active low output. Used to indicate the status of the power stage (amplifier enabled or disabled). The fault output will go to its active state upon a power stage fault, thermal overload, RMS current limit, power supply under voltage condition, and DC bus over voltage condition (detected if shunt fuse is open). Open collector output. Requires pull-up resistor to external power supply ranging from +5V to +30V.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Monitor Outputs         | <ul style="list-style-type: none"> <li>- <b>fdbk-Pin 12</b>: Current feedback monitor. When running a brushless motor, this signal represents the current in the motor phase A. When running a brush motor, this signal represents the entire motor current.</li> <li>- phase A: output is 8.3 A/V for BA50, 12.5 A/V for BA75, and 16.6 A/V for BA100.</li> <li>- <b>icmd-Pin 25</b>: Current command monitor. Representative of the current command. <math>\pm 5.5V</math> output. Equals peak current of amplifier 50 amps for BA50, 75 for BA75 and 100 for BA100.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                      |
| Power Inputs            | <ul style="list-style-type: none"> <li>- AC input: AC1, AC2, AC3, and earth ground (⏏), 56-230 VAC, 50-60 Hz, three phase. (<b>Note:</b> A single-phase supply can be connected to any two of the three AC input terminals. A single-phase supply can <u>only</u> be used with BA50 amplifier).<br/>23 amps RMS for BA50<br/>32 amps RMS for BA75<br/>45 amps RMS for BA100</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Motor Outputs           | <ul style="list-style-type: none"> <li>- <b>Motor</b> - phase A, phase B, phase C., 320 VDC maximum output. 18 amps RMS for the BA50, 25 amps RMS for the BA75, and 36 amps for the BA100.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Auxiliary Power Outputs | <ul style="list-style-type: none"> <li>- <b>5V-Pin 20</b>: On board 5V power supply. 250 mA maximum output.</li> <li>- <b>5V-Pin 2</b>: On board 5V power supply. Pin 2 is intended for powering an encoder. Can supply up to 250mA of current.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Connectors              | <ul style="list-style-type: none"> <li>- control: 25 pin “D” style female.</li> <li>- power: 8 terminal screw terminal for AC input and motor output.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

**Table 3-2. Electrical Specifications (Cont'd)**

| Feature              | Description                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Potentiometers       | <ul style="list-style-type: none"> <li>- Gain: adjusts preamp AC gain.</li> <li>- BALance: nulls command input DC offsets.</li> <li>- Tach: adjusts gain of tach or encoder derived velocity feedback input.</li> <li>- Input: adjusts gain of command input.</li> </ul>                                                                                                                                                                             |
| DIP Switches         | <ul style="list-style-type: none"> <li>- Peak current limit: 4 switches allow the user to set the peak current from 6-100% of max value.</li> <li>- RMS current limit: 4 switches allow the user to set the RMS current from 3-54% of max value.</li> <li>- Mode switch: This switch selects current or velocity mode.</li> <li>- Test: This switch selects test mode to allow the BALance pot to be used as velocity or current command.</li> </ul> |
| Protective Features  | <ul style="list-style-type: none"> <li>- Output short circuit</li> <li>- Peak over current</li> <li>- RMS over current</li> <li>- DC bus over voltage (detected if shunt fuse is open)</li> <li>- Over temperature</li> <li>- Control power supply under voltage</li> <li>- Power stage bias supply under voltage.</li> </ul>                                                                                                                        |
| Isolation            | - Opto and transformer isolation between control and power stages.                                                                                                                                                                                                                                                                                                                                                                                   |
| Indicator (power)    | - LED indicates drive power (green).                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Indicator (enabled)  | - LED indicates drive enabled (green).                                                                                                                                                                                                                                                                                                                                                                                                               |
| Indicator (fault)    | - LED indicator drive fault (red). Refer to Protective Features above.                                                                                                                                                                                                                                                                                                                                                                               |
| Indicator (overload) | - LED indicator RMS overload (red). Energized when RMS limit is exceeded. Will generate a 'fault' if limit is exceeded for more than two seconds.                                                                                                                                                                                                                                                                                                    |

### 3.3. BA Amplifier Dimensions

The outline dimensions for the BA amplifiers are shown in Figure 3-1 and Figure 3-2.

To ensure proper heat dissipation, Aerotech recommends the following procedures.

1. Use the mounting procedure shown in Figure 3-1, Figure 3-2, and Figure 3-3. For the BA50, the wider part of the amp should be mounted to the heat sink, if the application requires maximum continuous output current to the motor. For a typical servo system (e.g., intermittent duty cycle), the BA50 can be mounted standing up as shown in Figure 3-1. The BA75 and BA100 are always mounted standing up, see Figure 3-3.
2. The mounting base should be at least 2 feet<sup>2</sup> x 0.25" thick minimum and must be metal (aluminum or steel).
3. The heat sink should be free of paint or any other thermal Barrier.
4. The heat sink must be flat to allow good thermal conductivity between the heat sink and the amplifier.
5. If possible, add a thermal conductivity enhancer (i.e., thermal grease between the heat sink and the amplifier).
6. Adding an external fan will remove a considerable amount of heat from the heat sink and allow the amplifier to operate at a much cooler temperature.



The BA100 has an integral fan.



Heatsink and fan add 83.1 millimeters [3.27 inches] for BA75 and BA100 only.



It is advisable that the amplifier be mounted lying flat on a metal panel not less than two square feet for better heat dissipation. Refer to Figure 3-2.

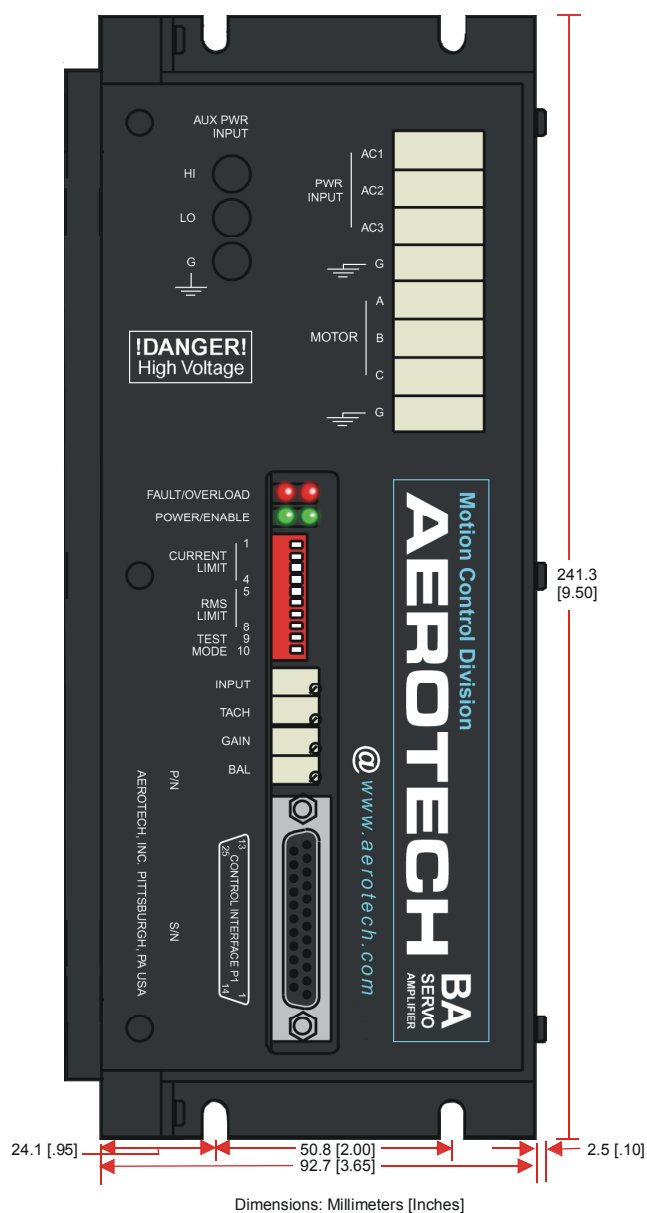


Figure 3-1. BA50 Dimensions (Front View)

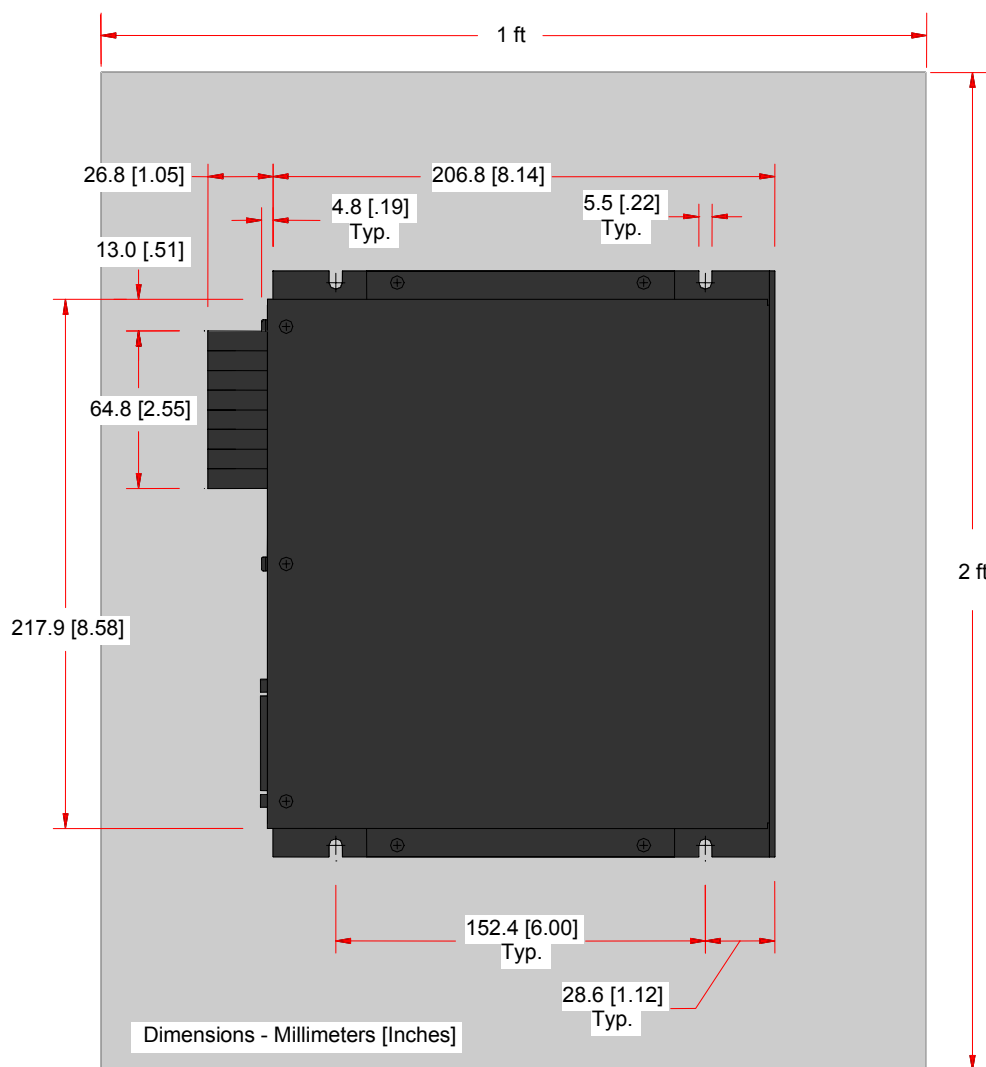


Figure 3-2. BA50 Preferred Mounting (Side View)

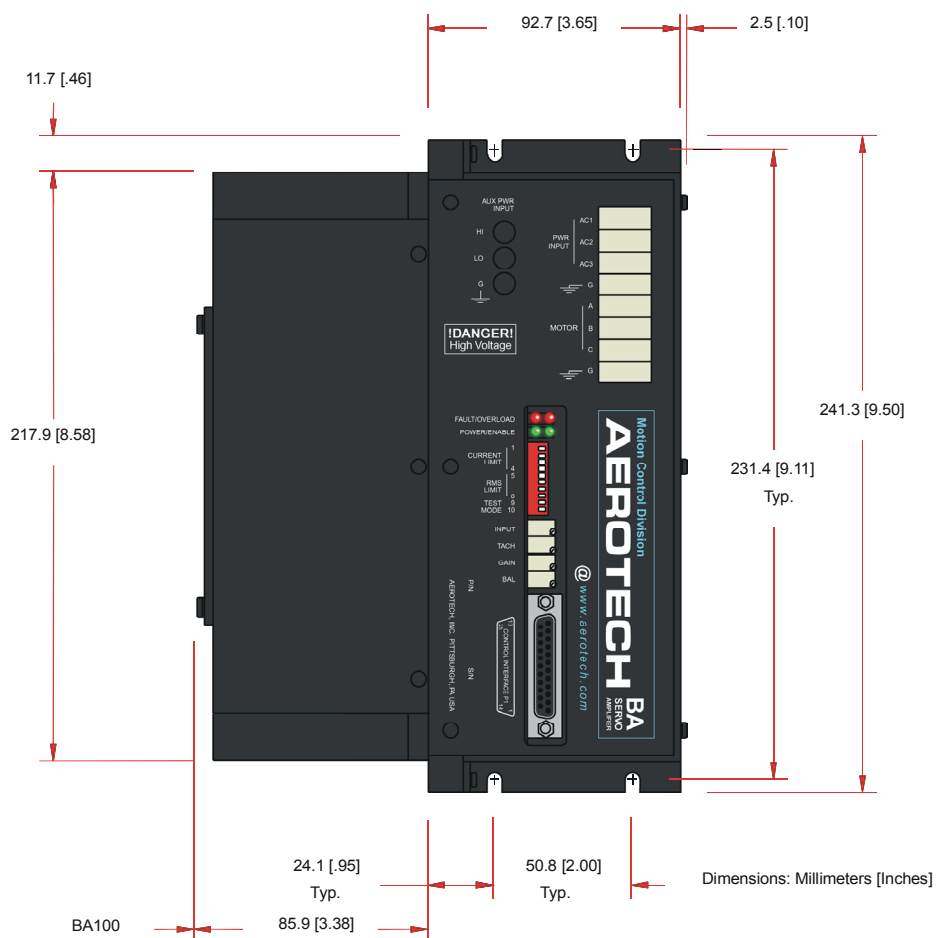


**Figure 3-3. BA75/100 Dimensions (Front View)**





## CHAPTER 4: TROUBLESHOOTING

### In This Section:

- Amplifier Related Problems ..... 4-1

### 4.1. Amplifier Related Problems

This section covers symptoms, probable causes and solutions related to the BA amplifier operation. Table 4-1 lists the most common symptoms of irregular operation and the possible causes and solutions for these faults.

Always disconnect the main power before servicing.

Before performing the tests described in Table 4-1, be aware that lethal voltages exist on the amplifier's PC board and at the input and output power connections. A qualified service technician or electrician should perform these tests.

Hazardous voltages may be present up to eight minutes after power is disconnected



WARNING



DANGER



WARNING

**Table 4-1. Amplifier Faults, Causes, and Solutions**

| Symptom                                                                    | Possible Cause and Solution                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| "POWER" and "ENABLE" LED fails to energize when AC input power is applied. | <ol style="list-style-type: none"> <li>1. Insufficient input voltage. Use voltmeter to check voltages at "AC1", "AC2", and "AC3" AC input terminals.</li> <li>2. Short circuit condition at motor connections A, B, and C. Disconnect motor connections from BA50 amplifier and check resistance at each terminal relative to the other terminal. Resistance should read the same for all terminals (between .5 and 2.0 <math>\Omega</math>, depending on motor).</li> <li>3. Short condition between motor connections and case of motor. Use ohmmeter to check resistance between all motor leads and motor frame. (Ensure the motor is disconnected from amplifier). Resistance should read "infinity".</li> <li>4. Shutdown, P1-10 is not at active state for running amplifier.</li> <li>5. If amplifier faults, remove AC for 30 seconds.</li> </ol> |
| Brushless motor will not spin in open loop current mode.                   | Motor phases A, B, and C connected incorrectly relative to HA, HB, and HC hall inputs. See section 2.5 for motor phasing information.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

**Table 4-1. Amplifier Faults, Causes, and Solutions - Continued**

| Symptom                                                                  | Possible Cause and Solution                                                                                                                                                                                                                                                                                                                                                                                           |
|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Motor spins uncontrollably in velocity mode configuration.               | Encoder (sine and cosine) signals or tach (+/-) signals are improperly connected. Swap connections to change polarity of feedback.                                                                                                                                                                                                                                                                                    |
| Amplifier faults ("FAULT" LED energizes) when motor decelerates.         | Shunt fuse is open. This condition indicates an excessive regeneration condition.                                                                                                                                                                                                                                                                                                                                     |
| Motor runs erratic in velocity mode using encoder for velocity feedback. | The phase of the sine and cosine signal of the encoder is not separated by 90°. The encoder must be adjusted on the motor.<br>Noise on the sine and cosine signals of the encoder. Use a shield or twisted pair (signal common wrapped around sine and cosine wires) cable between the motor and the BA amplifier.                                                                                                    |
| Amplifier Faults ("FAULT" LED energizes).                                | <ol style="list-style-type: none"> <li>1. RMS current exceeded - turn off and then back on, run at lower current.</li> <li>2. Over temperature condition - Turn off and let amplifier cool down. Provide better ventilation.</li> <li>3. Defective on board power supply - Return for repair.</li> <li>4. Over loaded logic power supply - Remove external device(s) being powered from the BA 5 V supply.</li> </ol> |

## 4.2. Fuse Replacement

Table 4-2 lists the replacement fuse part numbers (both Aerotech and manufacturer). Additional fuse information may be described in other documentation.

**Table 4-2. Fuse Replacement Part Numbers**

| Fuse               | Manufacture P/N     | Aerotech P/N |
|--------------------|---------------------|--------------|
| 3A, MDA (F1 shunt) | Buss; MDA-3         | EIF01017     |
| 5A, 3AG (F1 shunt) | Little Fuse; 313005 | EIF00105     |
| 8A, MDA (F1 shunt) | Buss; MDA-8         | EIF00122     |

Always disconnect the main power before opening the BA amplifier.



### **4.3. Cleaning**

The outside surface of the BA amplifier should be wiped with a clean, dry (or slightly moistened with water), soft cloth. Fluids and sprays are not recommended because internal contamination may result in electrical shorts and/or corrosion. The electrical power must be disconnected from the BA amplifier while cleaning. Do not allow cleaning substance to enter BA amplifier or onto any of the connectors. Cleaning Labels should be avoided to prevent removing printed user information.

▽ ▽ ▽

**APPENDIX A: GLOSSARY OF TERMS****In This Section:**

- Glossary ..... A-1

|                                  |                                                                                                                                                                                                                                                                             |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Abbe Error</b>                | The positioning error resulting from angular motion and an offset between the measuring device and the point of interest.                                                                                                                                                   |
| <b>Abbe Offset</b>               | The value of the offset between the measuring device and the point of interest.                                                                                                                                                                                             |
| <b>Absolute Move</b>             | A move referenced to a known point or datum.                                                                                                                                                                                                                                |
| <b>Absolute Programming</b>      | A positioning coordinate reference where all positions are specified relative to a reference or "home" position.                                                                                                                                                            |
| <b>AC Brushless Servo</b>        | A servomotor with stationary windings in the stator assembly and permanent magnet rotor. AC brushless generally refers to a sinusoidally wound motor (such as BM series) to be commutated via sinusoidal current waveform. (see DC Brushless Servo)                         |
| <b>Acceleration</b>              | The change in velocity as a function of time.                                                                                                                                                                                                                               |
| <b>Accuracy</b>                  | An absolute measurement defining the difference between actual and commanded position.                                                                                                                                                                                      |
| <b>Accuracy Grade</b>            | In reference to an encoder grating, accuracy grade is the tolerance of the placement of the graduations on the encoder scale.                                                                                                                                               |
| <b>ASCII</b>                     | American Standard Code for Information Interchange. This code assigns a number to each numeral and letter of the alphabet. Information can then be transmitted between machines as a series of binary numbers.                                                              |
| <b>Axial Runout</b>              | Positioning error of the rotary stage in the vertical direction when the tabletop is oriented in the horizontal plane. Axial runout is defined as the total indicator reading on a spherical ball positioned 50 mm above the tabletop and centered on the axis of rotation. |
| <b>Axis of Rotation</b>          | A center line about which rotation occurs.                                                                                                                                                                                                                                  |
| <b>Back emf, K<sub>emf</sub></b> | The voltage generated when a permanent magnet motor is rotated. This voltage is proportional to motor speed and is present whether or not the motor windings are energized.                                                                                                 |
| <b>Backlash</b>                  | A component of bidirectional repeatability, it is the non-responsiveness of the system load to reversal of input command.                                                                                                                                                   |

|                                    |                                                                                                                                                                                                                                                                                                                                                                                                                    |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Ball Screw</b>                  | A precision device for translating rotary motion into linear motion. A lead screw is a low-cost lower performance device performing the same function. Unit consists of an externally threaded screw and an internally threaded ball nut.                                                                                                                                                                          |
| <b>Ball Screw Lead</b>             | The linear distance a carriage will travel for one revolution of the ball screw (lead screw).                                                                                                                                                                                                                                                                                                                      |
| <b>Bandwidth</b>                   | A measurement, expressed in frequency (hertz), of the range which an amplifier or motor can respond to an input command from DC to -3dB on a frequency sweep.                                                                                                                                                                                                                                                      |
| <b>Baud Rate</b>                   | The number of bits transmitted per second on a serial communication channel such as RS-232 or modem.                                                                                                                                                                                                                                                                                                               |
| <b>BCD</b>                         | Binary Coded Decimal - A number system using four bits to represent 0-F (15).                                                                                                                                                                                                                                                                                                                                      |
| <b>Bearing</b>                     | A support mechanism allowing relative motion between two surfaces loaded against each other. This can be a rotary ball bearing, linear slide bearing, or air bearing (zero friction).                                                                                                                                                                                                                              |
| <b>Bidirectional Repeatability</b> | See Repeatability.                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>CAM Profile</b>                 | A technique used to perform nonlinear motion that is electronically similar to the motion achieved with mechanical cams.                                                                                                                                                                                                                                                                                           |
| <b>Cantilevered Load</b>           | A load not symmetrically mounted on a stage.                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Closed Loop</b>                 | A broad term relating to any system where the output is measured and compared to the input. Output is adjusted to reach the desired condition.                                                                                                                                                                                                                                                                     |
| <b>CNC</b>                         | Computer Numerical Control. A computer-based motion control device programmable in numerical word address format.                                                                                                                                                                                                                                                                                                  |
| <b>Coefficient of Friction</b>     | Defined as the ratio of the force required to move a given load to the magnitude of that load.                                                                                                                                                                                                                                                                                                                     |
| <b>Cogging</b>                     | Nonuniform angular/linear velocity. Cogging appears as a jerkiness, especially at low speeds, and is due to magnetic poles attracting to steel laminations.                                                                                                                                                                                                                                                        |
| <b>Commutation</b>                 | The action of steering currents to the proper motor phases to produce optimum motor torque/force. In brush-type motors, commutation is done electromechanically via the brushes and commutator. A brushless motor is electronically commutated using a position feedback device such as an encoder or Hall effect devices. Stepping motors are electronically commutated without feedback in an open-loop fashion. |

**Commutation, 6-Step** Also referred to as trapezoidal commutation. The process of switching motor phase current based on three Hall effect signals spaced 120 electrical degrees beginning 30 degrees into the electrical cycle. This method is the easiest for commutation of brushless motors.

**Commutation, Modified 6-Step** Also referred to as modified sine commutation. The process of switching motor phase current based on three Hall effect signals spaced 120 electrical degrees beginning at 0 electrical degrees. This method is slightly more difficult to implement than standard 6-step, but more closely approximates the motor's back emf. The result is smoother control and less ripple. Aerotech's BA series self-commutate using this method.

**Commutation, Sinusoidal** The process of switching motor phase current based on motor position information, usually from an encoder. In this method, the three phase currents are switched in very small increments that closely resemble the motor's back emf. Sinusoidal commutation requires digital signal processing to convert position information into three-phase current values and, consequently, is most expensive to implement. The result, however, is the best possible control. All Aerotech controllers, as well as the BAS series amplifiers, commute using this method.

**Coordinated Motion** Multi-axis motion where the position of each axis is dependent on the other axis, such that the path and velocity of a move can be accurately controlled. Drawing a circle requires coordinated motion.

**Critical Speed** A term used in the specification of a lead screw or ball screw indicating the maximum rotation speed before resonance occurs. This speed limit is a function of the screw diameter, distance between support bearings, and bearing rigidity.

**Current Command** Motor driver or amplifier configuration where the input signal is commanding motor current directly, which translates to motor torque/force at the motor output. Brushless motors can be commutated directly from a controller that can output current phase A and B commands.

**Current, Peak** An allowable current to run a motor above its rated load, usually during starting conditions. Peak current listed on a data sheet is usually the highest current safely allowed to the motor.

**Current, rms** Root Mean Square. Average of effective currents over an amount of time. This current is calculated based on the load and duty cycle of the application.

|                             |                                                                                                                                                                                                                                                                                                                                                  |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Cycle</b>                | When motion is repeated (move and dwell) such as repetitive back-and-forth motion.                                                                                                                                                                                                                                                               |
| <b>DC Brushless Servo</b>   | A servomotor with stationary windings in the stator assembly and permanent magnet rotor. (See AC Brushless Servo)                                                                                                                                                                                                                                |
| <b>Deceleration</b>         | The change in velocity as a function of time.                                                                                                                                                                                                                                                                                                    |
| <b>Duty Cycle</b>           | For a repetitive cycle, the ratio of “on” time to total cycle time used to determine a motor’s rms current and torque/force.                                                                                                                                                                                                                     |
| <b>Dwell Time</b>           | Time in a cycle at which no motion occurs. Used in the calculation of rms power.                                                                                                                                                                                                                                                                 |
| <b>Efficiency</b>           | Ratio of input power vs. output power.                                                                                                                                                                                                                                                                                                           |
| <b>Electronic Gearing</b>   | Technique used to electrically simulate mechanical gearing. Causes one closed loop axis to be slaved to another open or closed loop axis with a variable ratio.                                                                                                                                                                                  |
| <b>Encoder Marker</b>       | Once-per-revolution signal provided by some incremental encoders to accurately specify a reference point within that revolution. Also known as Zero Reference Signal or Index Pulse.                                                                                                                                                             |
| <b>Encoder Resolution</b>   | Measure of the smallest positional change which can be detected by the encoder. A 1000-line encoder with a quadrature output will produce 4000 counts per revolution.                                                                                                                                                                            |
| <b>Encoder, Incremental</b> | Position encoding device in which the output is a series of pulses relative to the amount of movement.                                                                                                                                                                                                                                           |
| <b>Feedback</b>             | Signal that provides process or loop information such as speed, torque, and position back to the controller to produce a “closed loop” system.                                                                                                                                                                                                   |
| <b>Flatness (of travel)</b> | Measure of the vertical deviation of a stage as it travels in a horizontal plane.                                                                                                                                                                                                                                                                |
| <b>Force, Continuous</b>    | The value of force that a particular motor can produce in a continuous stall or running (as calculated by the rms values) condition.                                                                                                                                                                                                             |
| <b>Force, Peak</b>          | The maximum value of force that a particular motor can produce. When sizing for a specific application, the peak force is usually that required during acceleration and deceleration of the move profile. The peak force is used in conjunction with the continuous force and duty cycle to calculate the rms force required by the application. |
| <b>Friction</b>             | The resistance to motion between two surfaces in contact with each other.                                                                                                                                                                                                                                                                        |

|                            |                                                                                                                                                                                                                                                            |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>G.P.I.B.</b>            | A standard protocol, analogous to RS-232, for transmitting digital information. The G.P.I.B. interface (IEEE-488) transmits data in parallel instead of serial format. (See IEEE-488)                                                                      |
| <b>Gain</b>                | Comparison or ratio of the output signal and the input signal. In general, the higher the system gain, the higher the response.                                                                                                                            |
| <b>Grating Period</b>      | Actual distance between graduations on an encoder.                                                                                                                                                                                                         |
| <b>Hall Effect Sensors</b> | Feedback device (HED) used in a brushless servo system to provide information for the amplifier to electronically commutate the motor.                                                                                                                     |
| <b>HED</b>                 | Hall Effect Device. (See Hall Effect Sensors)                                                                                                                                                                                                              |
| <b>HMI</b>                 | Human Machine Interface. Used as a means of getting operator data into the system. (See MMI)                                                                                                                                                               |
| <b>Home</b>                | Reference position for all absolute positioning movements. Usually defined by a home limit switch and/or encoder marker.                                                                                                                                   |
| <b>Home Switch</b>         | A sensor used to determine an accurate starting position for the home cycle.                                                                                                                                                                               |
| <b>Hysteresis</b>          | A component of bidirectional repeatability. Hysteresis is the deviation between actual and commanded position and is created by the elastic forces in the drive systems.                                                                                   |
| <b>I/O</b>                 | Input / Output. The reception and transmission of information between control devices using discrete connection points.                                                                                                                                    |
| <b>IEEE-488</b>            | A set of codes and formats to be used by devices connected via a parallel bus system. This standard also defines communication protocols that are necessary for message exchanges, and further defines common commands and characteristics. (See G.P.I.B.) |
| <b>Incremental Move</b>    | A move referenced from its starting point (relative move).                                                                                                                                                                                                 |
| <b>Inertia</b>             | The physical property of an object to resist changes in velocity when acted upon by an outside force. Inertia is dependent upon the mass and shape of an object.                                                                                           |
| <b>Lead Error</b>          | The deviation of a lead screw or ball screw from its nominal pitch.                                                                                                                                                                                        |
| <b>Lead Screw</b>          | A device for translating rotary motion into linear motion. Unit consists of an externally threaded screw and an internally threaded carriage (nut). (See Ball Screw)                                                                                       |

|                                 |                                                                                                                                                                                                                 |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Life</b>                     | The minimum rated lifetime of a stage at maximum payload while maintaining positioning specifications.                                                                                                          |
| <b>Limit Switch</b>             | A sensor used to determine the end of travel on a linear motion assembly.                                                                                                                                       |
| <b>Limits</b>                   | Sensors called limits that alert the control electronics that the physical end of travel is being approached and motion should stop.                                                                            |
| <b>Linear Motor</b>             | A motor consisting of 2 parts, typically a moving coil and stationary magnet track. When driven with a standard servo amplifier, it creates a thrust force along the longitudinal axis of the magnet track.     |
| <b>Load Carrying Capability</b> | The maximum recommended payload that does not degrade the listed specifications for a mechanical stage.                                                                                                         |
| <b>Master-Slave</b>             | Type of coordinated motion control where the master axis position is used to generate one or more slave axis position commands.                                                                                 |
| <b>MMI</b>                      | Man Machine Interface used as a means of getting operator data into the system. (See HMI)                                                                                                                       |
| <b>Motion Profile</b>           | A method of describing a process in terms of velocity, time, and position.                                                                                                                                      |
| <b>Motor Brush</b>              | The conductive element in a DC brush-type motor used to transfer current to the internal windings.                                                                                                              |
| <b>Motor, Brushless</b>         | Type of direct current motor that utilizes electronic commutation rather than brushes to transfer current.                                                                                                      |
| <b>Motor, Stepping</b>          | Specialized motor that allows discrete positioning without feedback. Used for noncritical, low power applications, since positional information is easily lost if acceleration or velocity limits are exceeded. |
| <b>NC</b>                       | Numerical Control. Automated equipment or process used for contouring or positioning. (See CNC)                                                                                                                 |
| <b>NEMA</b>                     | National Electrical Manufacturer's Association. Sets standards for motors and other industrial electrical equipment.                                                                                            |
| <b>Non-Volatile Memory</b>      | Memory in a system that maintains information when power is removed.                                                                                                                                            |
| <b>Open Collector</b>           | A signal output that is performed with a transistor. Open collector output acts like a switch closure with one end of the switch at circuit common potential and the other end of the switch accessible.        |
| <b>Open Loop</b>                | Control circuit that has an input signal only, and thus cannot make any corrections based on external influences.                                                                                               |

|                           |                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Operator Interface</b> | Device that allows the operator to communicate with a machine. A keyboard or thumbwheel is used to enter instructions into a machine. (See HMI or MMI)                                                                                                                                                                                                         |
| <b>Optical Encoder</b>    | A linear or angular position feedback device using light fringes to develop position information.                                                                                                                                                                                                                                                              |
| <b>Opto-isolated</b>      | System or circuit that transmits signal with no direct electrical connections, using photoelectric coupling between elements.                                                                                                                                                                                                                                  |
| <b>Orthogonality</b>      | The condition of a surface or axis which is perpendicular (offset 90 degrees) to a second surface or axis. Orthogonality specification refers to the error from 90 degrees from which two surfaces of axes are aligned.                                                                                                                                        |
| <b>Overshoot</b>          | In a servo system, referred to the amount of velocity and/or position overrun from the input command. Overshoot is a result of many factors including mechanical structure, tuning gains, servo controller capability, and inertial mismatch.                                                                                                                  |
| <b>PID</b>                | A group of gain terms in classical control theory (Proportional Integral Derivative) used in compensation of a closed-loop system. The terms are optimally adjusted to have the output response equal the input command. Aerotech controllers utilize the more sophisticated PID FVFA loop which incorporates additional terms for greater system performance. |
| <b>Pitch (of travel)</b>  | Angular motion of a carriage around an axis perpendicular to the motion direction and perpendicular to the yaw axis.                                                                                                                                                                                                                                           |
| <b>Pitch Error</b>        | Positioning error resulting from a pitching motion.                                                                                                                                                                                                                                                                                                            |
| <b>PLC</b>                | Programmable Logic Controller. A programmable device that utilizes "ladder logic" to control a number of input and output discrete devices.                                                                                                                                                                                                                    |
| <b>PWM</b>                | Pulse Width Modulation. Switch-mode technique used in amplifiers and drivers to control motor current. The output voltage is constant and switched at the bus value (160 VDC with a 115 VAC input line).                                                                                                                                                       |
| <b>Quadrature</b>         | Refers to the property of position transducers that allows them to detect direction of motion using the phase relationship of two signal channels. A 1000-line encoder will yield 4000 counts via quadrature.                                                                                                                                                  |
| <b>Radial Runout</b>      | Positioning error of the rotary stage in the horizontal direction when the tabletop is oriented in the horizontal plane. Radial runout is defined as the total indicator reading on a spherical ball positioned 50 mm above the tabletop and centered on the axis of rotation.                                                                                 |
| <b>Ramp Time</b>          | Time it takes to accelerate from one velocity to another.                                                                                                                                                                                                                                                                                                      |

|                         |                                                                                                                                                                                                                                                                                                                                    |
|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Range</b>            | The maximum allowable travel of a positioning stage.                                                                                                                                                                                                                                                                               |
| <b>RDC</b>              | Resolver to Digital Converter. Electronic component that converts the analog signals from a resolver (transmitter type) into a digital word representing angular position.                                                                                                                                                         |
| <b>Repeatability</b>    | The maximum deviation from the mean (each side) when repeatedly approaching a position. Unidirectional repeatability refers to the value established by moving toward a position in the same direction. Bidirectional repeatability refers to the value established by moving toward a position in the same or opposite direction. |
| <b>Resolution</b>       | The smallest change in distance that a device can measure.                                                                                                                                                                                                                                                                         |
| <b>Retroreflector</b>   | An optical element with the property that an input light beam is reflected and returns along the same angle as the input beam. Used with laser interferometers.                                                                                                                                                                    |
| <b>Roll (of travel)</b> | Angular motion of a carriage around an axis parallel to the motion direction and perpendicular to the yaw axis.                                                                                                                                                                                                                    |
| <b>Roll Error</b>       | Positioning error resulting from a roll motion.                                                                                                                                                                                                                                                                                    |
| <b>Rotor</b>            | The rotating part of a magnetic structure. In a motor, the rotor is connected to the motor shaft.                                                                                                                                                                                                                                  |
| <b>RS-232C</b>          | Industry standard for sending signals utilizing a single-ended driver/receiver circuit. As such, the maximum distance is limited based on the baud rate setting but is typically 50-100 feet. This standard defines pin assignments, handshaking, and signal levels for receiving and sending devices.                             |
| <b>RS-274</b>           | Industry standard programming language. Also referred to as G-code machine programming. A command set specific for the machine tool industry that defines geometric moves.                                                                                                                                                         |
| <b>RS-422</b>           | Industry communication standard for sending signals over distances up to 4000 feet. Standard line driver encoder interfaces utilize RS-422 because of the noise immunity.                                                                                                                                                          |
| <b>Runout</b>           | The deviation from the desired form of a surface during full rotation (360 degrees) about an axis. Runout is measured as total indicated reading (TIR). For a rotary stage, axis runout refers to the deviation of the axis of rotation from the theoretical axis of rotation.                                                     |
| <b>Servo System</b>     | Refers to a closed loop control system where a command is issued for a change in position and the change is then verified via a feedback system.                                                                                                                                                                                   |

|                                      |                                                                                                                                                                                              |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Settling Time</b>                 | Time required for a motion system to cease motion once the command for motion has ended.                                                                                                     |
| <b>Shaft Radial Load</b>             | Maximum radial load that can be applied to the end of the motor shaft at maximum motor speed.                                                                                                |
| <b>Shaft Runout</b>                  | Deviation from straight line travel.                                                                                                                                                         |
| <b>Slotless</b>                      | Describes the type of laminations used in a motor that eliminates cogging torque due to magnetic attraction of the rotor to the stator slots.                                                |
| <b>Stator</b>                        | Non-rotating part of a magnetic structure. In a motor, the stator usually contains the mounting surface, bearings, and non-rotating windings.                                                |
| <b>Stiction</b>                      | Friction encountered when accelerating an object from a stationary position. Static friction is always greater than moving friction, and limits the smallest possible increment of movement. |
| <b>Straightness of Travel</b>        | Measure of the side-to-side deviation of a stage as it travels in a horizontal plane.                                                                                                        |
| <b>Torque</b>                        | Rotary equivalent to force. Equal to the product of the force perpendicular to the radius of motion and distance from the center of rotation to the point where the force is applied.        |
| <b>Torque, Continuous</b>            | Torque needed to drive a load over a continuous time.                                                                                                                                        |
| <b>Torque, Peak</b>                  | Maximum amount of torque a motor can deliver when the highest allowable peak currents are applied.                                                                                           |
| <b>Torque, rms</b>                   | Root Mean Square is a mathematical method to determine a steadfast or average torque for a motor.                                                                                            |
| <b>Torque, Stall</b>                 | The maximum torque without burning out the motor.                                                                                                                                            |
| <b>Total Indicated Reading (TIR)</b> | The full indicator reading observed when a dial indicator is in contact with the part surface during one full revolution of the part about its axis of rotation.                             |
| <b>Tuning</b>                        | In a servo system, the process of optimizing loop gains (usually PID terms) to achieve the desired response from a stage or mechanism from an input command.                                 |
| <b>Unidirectional Repeatability</b>  | See Repeatability                                                                                                                                                                            |
| <b>Velocity Command</b>              | Motor driver or amplifier configuration where the input signal is commanding motor velocity. Motors with analog tachometers are normally driven by this driver configuration.                |

|                        |                                                                                                                                                                                                               |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wobble</b>          | An irregular, non-repeatable rocking or staggering motion of the table top of a rotary stage. Wobble is defined as an angular error between the actual axis of rotation and the theoretical axis of rotation. |
| <b>Yaw (of travel)</b> | Rotation about the vertical axis, perpendicular to the axis of travel. Angular movement (error) that affects straightness and positioning accuracy.                                                           |
| <b>Yaw Error</b>       | Positioning error resulting from a yaw motion.                                                                                                                                                                |

▽ ▽ ▽

## APPENDIX B: WARRANTY AND FIELD SERVICE

### In This Section:

- Laser Products ..... B-1
- Return Procedure ..... B-1
- Returned Product Warranty Determination ..... B-2
- Returned Product Non-warranty Determination..... B-2
- Rush Service..... B-2
- On-site Warranty Repair..... B-2
- On-site Non-warranty Repair ..... B-2

Aerotech, Inc. warrants its products to be free from defects caused by faulty materials or poor workmanship for a minimum period of one year from date of shipment from Aerotech. Aerotech's liability is limited to replacing, repairing or issuing credit, at its option, for any products that are returned by the original purchaser during the warranty period. Aerotech makes no warranty that its products are fit for the use or purpose to which they may be put by the buyer, whether or not such use or purpose has been disclosed to Aerotech in specifications or drawings previously or subsequently provided, or whether or not Aerotech's products are specifically designed and/or manufactured for buyer's use or purpose. Aerotech's liability or any claim for loss or damage arising out of the sale, resale or use of any of its products shall in no event exceed the selling price of the unit.

Aerotech, Inc. warrants its laser products to the original purchaser for a minimum period of one year from date of shipment. This warranty covers defects in workmanship and material and is voided for all laser power supplies, plasma tubes and laser systems subject to electrical or physical abuse, tampering (such as opening the housing or removal of the serial tag) or improper operation as determined by Aerotech. This warranty is also voided for failure to comply with Aerotech's return procedures.

### *Laser Products*

Claims for shipment damage (evident or concealed) must be filed with the carrier by the buyer. Aerotech must be notified within (30) days of shipment of incorrect materials. No product may be returned, whether in warranty or out of warranty, without first obtaining approval from Aerotech. No credit will be given nor repairs made for products returned without such approval. Any returned product(s) must be accompanied by a return authorization number. The return authorization number may be obtained by calling an Aerotech service center. Products must be returned, prepaid, to an Aerotech service center (no C.O.D. or Collect Freight accepted). The status of any product returned later than (30) days after the issuance of a return authorization number will be subject to review.

### *Return Procedure*

After Aerotech's examination, warranty or out-of-warranty status will be determined. If upon Aerotech's examination a warranted defect exists, then the product(s) will be repaired at no charge and shipped, prepaid, back to the buyer. If the buyer desires an air freight return, the product(s) will be shipped collect. Warranty repairs do not extend the original warranty period.

### *Returned Product Warranty Determination*

***Returned Product Non-warranty Determination***

After Aerotech's examination, the buyer shall be notified of the repair cost. At such time the buyer must issue a valid purchase order to cover the cost of the repair and freight, or authorize the product(s) to be shipped back as is, at the buyer's expense. Failure to obtain a purchase order number or approval within (30) days of notification will result in the product(s) being returned as is, at the buyer's expense. Repair work is warranted for (90) days from date of shipment. Replacement components are warranted for one year from date of shipment.

***Rush Service***

At times, the buyer may desire to expedite a repair. Regardless of warranty or out-of-warranty status, the buyer must issue a valid purchase order to cover the added rush service cost. Rush service is subject to Aerotech's approval.

***On-site Warranty Repair***

If an Aerotech product cannot be made functional by telephone assistance or by sending and having the customer install replacement parts, and cannot be returned to the Aerotech service center for repair, and if Aerotech determines the problem could be warranty-related, then the following policy applies:

Aerotech will provide an on-site field service representative in a reasonable amount of time, provided that the customer issues a valid purchase order to Aerotech covering all transportation and subsistence costs. For warranty field repairs, the customer will not be charged for the cost of labor and material. If service is rendered at times other than normal work periods, then special service rates apply.

If during the on-site repair it is determined the problem is not warranty related, then the terms and conditions stated in the following "On-Site Non-Warranty Repair" section apply.

***On-site Non-warranty Repair***

If any Aerotech product cannot be made functional by telephone assistance or purchased replacement parts, and cannot be returned to the Aerotech service center for repair, then the following field service policy applies:

Aerotech will provide an on-site field service representative in a reasonable amount of time, provided that the customer issues a valid purchase order to Aerotech covering all transportation and subsistence costs and the prevailing labor cost, including travel time, necessary to complete the repair.

***Company Address***

Aerotech, Inc.  
101 Zeta Drive  
Pittsburgh, PA 15238-2897  
USA

Phone: (412) 963-7470  
Fax: (412) 963-7459

▽ ▽ ▽

## APPENDIX C: CABLE DRAWINGS

## In This Section:

- Description.....C-1

## Description

The following section provides the user with 2 reference drawings for connecting Aerotech cables to the BA amplifiers.

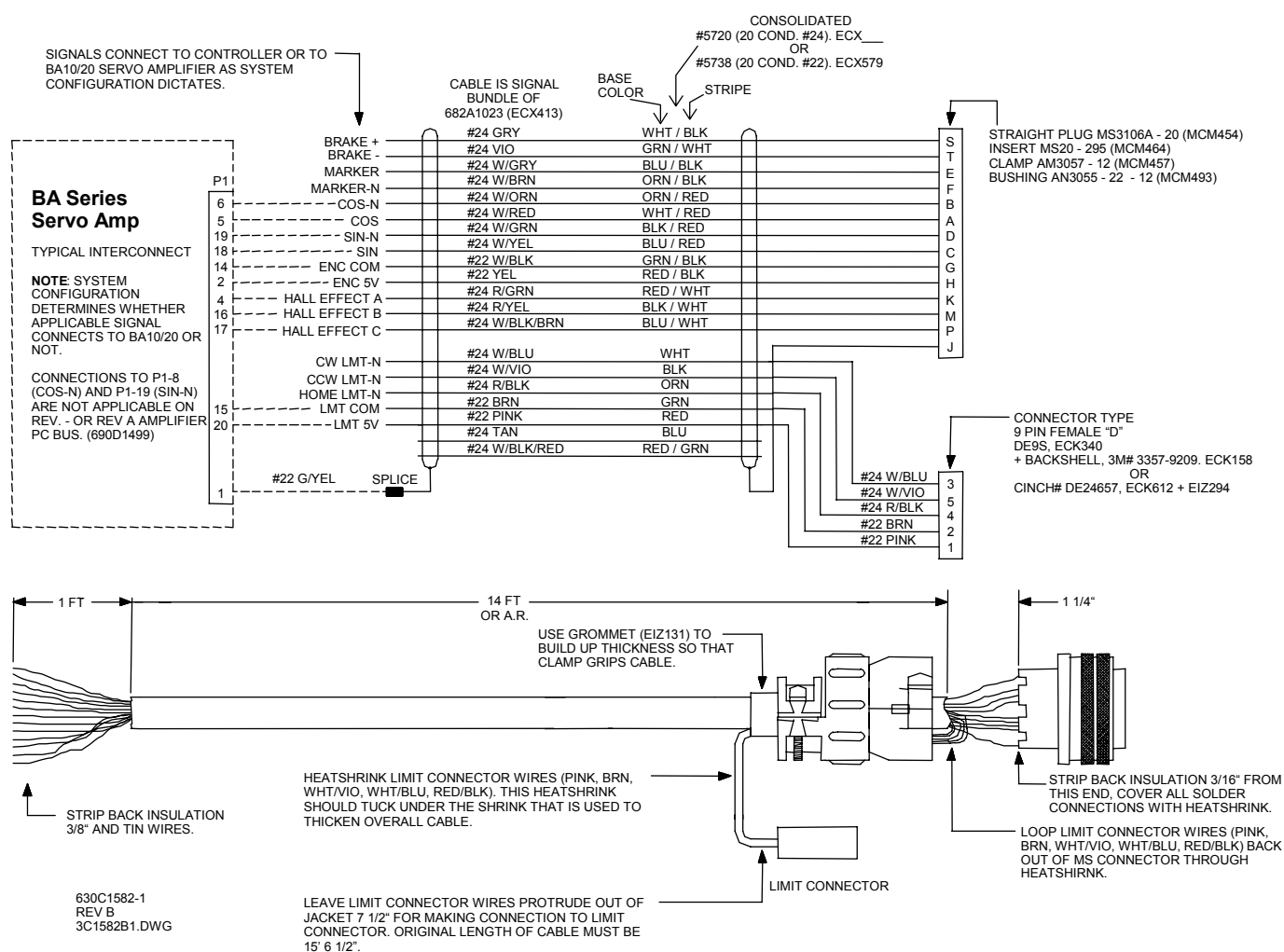


Figure C-1. BA Feedback Cable (PFC)

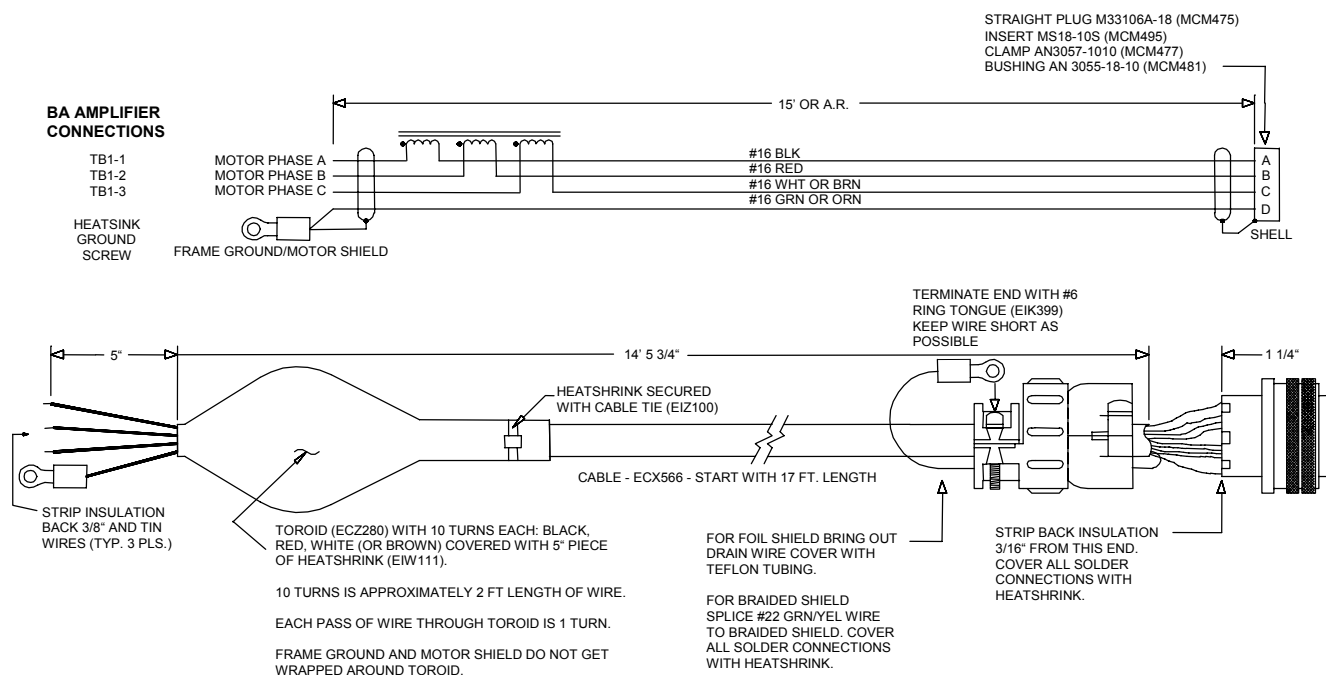


**Figure C-2. BA Series Light Duty Brushless Motor Cable (PMC) (BA 50 only)**

▽ ▽ ▽

+  
+/- Limit Inputs Circuitry, 1-10

## A

Accessories, 3-1  
Amplifier Faults, 4-1, 4-3  
Amplifier Hardware, 1-4  
Amplifier Related Problems, 4-1  
Applications, 1-1

## B

BALance Pot, 1-6  
Board assembly, 2-3  
Brushless Motor Cable, C-2

## C

Cable, C-1, C-2  
Capacitive Coupling, 2-4, 2-5  
Cleaning, 4-4  
Connector, 1-4, 3-2  
Connector P1, 1-6, 2-13  
Connector P1 Pinouts, 1-7  
Control Connections, 2-10  
Current, 1-5  
Current Command, 2-7, 2-8  
Current Regulator Adjustment, 2-15

## D

Differential Input, 2-9  
DIP Switch, 1-4, 1-5  
    Functions, 1-5  
Drive Package, 1-3  
Dual Phase Command, 2-7, 2-9  
Dual Phase Command Mode, 2-12

## E

Electrical Specifications, 3-2  
EMI, 2-5  
EMI Interference, 2-4  
ENABLE LED, 1-6  
Enable/Shutdown Input Circuitry, 1-9  
Encoder, 2-7  
Encoders, 1-2  
External Controller, 2-7

## F

Fault conditions, 1-2

FAULT LED, 1-6  
Fault Output Circuitry, 1-9  
Feedback Cable, C-1  
Feedback signals, 1-2  
Field Service Policy, B-1  
Functional diagram, 1-3

## G

GAIN Pot, 1-6  
Grounding Techniques, 2-4

## H

Hall and Encoder Inputs Circuitry, 1-10  
Hall Connections, 2-13  
Hall Effect Device, 1-2  
Hardware  
    Function, 1-4  
    Overview, 1-4

## I

I/O Circuitry, 1-9  
IFDBK, 2-16  
INPUT Pot, 1-6  
Integrated, 2-7  
Integrated Configurations, 2-7  
Isolation Transformer, 2-6

## J

Jumper, 2-2  
Jumper Selections, 2-1

## L

LED indicator, 1-4  
Line Filter Connection, 2-5  
Line Interference, 2-5

## M

Mechanical Drawings, 3-6  
Mode, 1-6  
Models, 1-2  
Motor, 2-14  
Motor Phasing, 2-13

## N

Noise  
    Back-Propagation, 2-5

**O**

Operating modes, 1-2  
Options, 1-2  
Order Information, 3-1  
OVERLOAD LED, 1-6

**P**

Part Number Information, 3-1  
Phase Hall Sequence, 2-13  
Position, 2-8  
Potentiometer Functions, 1-6  
Potentiometers, 1-4, 1-6  
Power, 1-2  
Power Connections, 1-4, 2-10  
POWER LED, 1-6  
Pre-Amplifier Circuit, 2-9  
Precautions, 1-11  
Preferred, 3-8  
Product Overview, 1-1

**R**

RCN1, 2-16

**S**

Safety Procedures, 1-11  
Self-Commutation, 2-9  
Shielding Techniques, 2-4  
Switching Rate, 2-4

**T**

TACH Pot, 1-6  
Tachometer, 2-7  
Test, 1-5  
Torque Command Bode, 2-10  
Troubleshooting, 4-1

**V**

Velocity, 1-5, 2-7  
Velocity Command, 2-7  
Velocity Command Mode, 2-10  
Voltage Configurations, 1-2

**W**

Warnings, 1-11  
Warranty Policy, B-1  
Wiring Techniques, 2-4

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## READER'S COMMENTS

### BA50/75/100 Series User's Manual P/N EDA 140, June 2004

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